DOCUMENT RESUME

ED 295 056 CE 050 331

TITLE	A Model Secondary/Postsecondary Program to Prepare Students for Employment in High Technology Occupations. Final Report.
INSTITUTION	Center for Occupational Research and Development, Inc., Waco, Tex.
SPONS AGENCY	Leander Independent School District, TX.
PUB DATE	[87]
NOTE	102p.; Portions of appendixes contain small print.
PUB TYPE	Reports - Research/Technical (143) -- Tests/Evaluation Instruments (160)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Articulation (Education); *Community Colleges; Cooperative Planning; Cooperative Programs; Coordination; *Curriculum Development; Electronic Control; Models; Postsecondary Education; Secondary Education; Statewide Planning; *Technical Education; Technical Occupations; *Technological Advancement
IDENTIFIERS	*Texas

ABSTRACT

The Leander Independent School District in Austin, Texas, undertook a project to (1) research the training needs for high-technology occupations in the Greater Austin area, (2) develop a statewide model of an articulated 2 + 2 program to prepare students for careers as technicians, and (3) implement the articulated 2 + 2 program with Austin Community College. (The term 2 + 2 means coordination of the last two years of high school with two years of postsecondary course work.) Both a mailed survey and a series of in-depth interviews were conducted with representatives from advanced technology industries in the Austin area. After a review of the results, work to develop a curriculum to train instrumentation and control technicians was begun. A list of job competencies was developed from the data obtained during the survey and interviews and subsequently sent to eight Austin-area industry representatives for evaluation, whose directives were compiled to form the basis of the curriculum design. The curriculum delivery system was then analyzed in the light of current course offerings in the Leander Independent School District and Austin Community College. Decisions were also reached as to the way in which the curriculum would fit into the overall plan generally followed by high school students, and on the mechanics of developing the mechanics of developing an articulated 2 + 2 agreement between the two schools. Draft and final versions of the agreement were ultimately developed. Appendixes make up the greater part of the document. They include the survey questionnaire and cover letter, interview guide, competency evaluation form, a table showing correlation of competencies to course content, a guide for developing a 2 + 2 curriculum, instrumentation and control curriculum course outlines, a chart showing alternative entry points for the curriculum, guidelines for developing lecture and laboratory facilities, and reference materials used for the curriculum. (MN)

TK 8713309
#1731-6-23-86-007

ED295056

LEANDER INDEPENDENT SCHOOL DISTRICT

AUSTIN COMMUNITY COLLEGE

A Model Secondary/Postsecondary Program to Prepare Students for Employment in High Technology Occupations

Project #77420061

FINAL REPORT

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FINAL REPORT

A Model Secondary/Postsecondary Program to Prepare Students for Employment in High Technology Occupations

TEA Project #77420061

prepared for

Leander Independent School District

and

The Texas Education Agency

Center for Occupational Research and Development

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2 + 2 ARTICULATION FOR TECHNICAL EDUCATION

IN THE AUSTIN AREA

2 + 2 ARTICULATION---

COORDINATED SECONDARY/POSTSECONDARY CURRICULUM

The concept of 2 + 2 articulation has been under discussion for 20 years, yet some confusion still has remained among educators and the public about just what "2 + 2 articulation" actually means. Stated simply, 2 + 2 articulation has been a formal agreement between secondary and postsecondary schools to implement a program of education in which duplication of coursework is eliminated. In addition, secondary-level students will learn entry-level technical job competencies---competencies usually taught at the postsecondary level. Within an articulated curriculum, students effectively will begin a postsecondary program of study while they are in high school.

The term, "2 + 2," has referred to coordinating, or aligning, the last two years of high school coursework with two years of postsecondary coursework. In this discussion, "2 + 2" will refer to coordinating two years of secondary vocational education coursework at Leander Independent School District with two years of technical postsecondary coursework at Austin Community College.

"Articulation" will refer to the joining or interfacing of secondary and postsecondary curricula. This "joining" will occur through articulated courses---courses taught at the secondary-level institution. These courses will teach the same competencies as courses at the postsecondary level. The students will receive secondary-level credit for successfully completing the articulated courses. A "credit in escrow" system will provide a vehicle for giving students credit at the postsecondary level for work they have completed during high school.

THE VALUE OF 2 + 2 ARTICULATED TECHNICAL EDUCATION PROGRAMS

Students will be the primary beneficiaries of 2 + 2 articulated programs. Secondary students will receive a view of several career paths available through postsecondary training, and saleable skills. Through 2 + 2 articulation, students are placed "on track" to attend postsecondary schools.

Postsecondary students get a head start on learning the competencies required in the job market, a chance for higher wages, an understanding of the "success factors" that lead to rewarding careers, and improved job security.

Secondary schools will benefit by having a coordinated curriculum that presents a vibrant--and more visible--image for vocational/technical programs, helps revive the team spirit among faculty in its holistic approach to education, helps faculty streamline the education process, and encourages students to complete high school.

Postsecondary schools will benefit by getting more and better-prepared incoming students. This will provide a chance to move basic technical skills training to secondary schools and, as a result, improve the breadth and depth of technical training programs, giving graduates a better image because they emerge with a greater depth of competency.

In the Austin area, business will benefit by having access to technicians---as well as other members of the labor force---who are prepared to work more productively in a more competitive global economy. This will be an important consideration. Presently, the skilled labor pool has been dwindling---there simply are not as many young people, and the jobs of the future will require higher levels of skill than can be acquired at the high school level. At the same time, because of technological advances, many of our nation's older workers have a range of skills that are becoming outdated. It should be feasible that outgrowths of 2 + 2 articulation programs---can serve as catalysts for finding ways to update the skills of workers now on the job so that their skills do not become obsolete.

Furthermore, taxpayers will benefit through education partnerships that facilitate fewer wasted dollars due to program duplication--- partnerships that link the goals of education with economic development.

PROJECT GOALS

Leander Independent School District's "Articulation (2 + 2) Project" goals were: (1) to research the training needs for high-technology occupations in the Greater Austin area, (2) to develop a statewide model of an articulated 2 + 2 program that prepares students for careers as technicians, and (3) to implement the articulated 2 + 2 program with Austin Community College. Leander I.S.D. representatives selected the Center for Occupational Research and Development (CORD) in Waco, Texas, to help carry out the project's goals.

PROJECT EVALUATION OBJECTIVES

Texas Education Agency objectives for this project are listed below. Each objective has been addressed within this report. To facilitate the evaluation process, the report page number addressing each objective has been given.

Was research on the training needs in high-technology occupations accomplished? (Page 7.)

Was the development of an articulated (2+2) training program in high technology accomplished? (Page 22.)

Were research and/or development activities approved by a steering committee as specified? (Page 7.)

Was the program developed for two years of training in the secondary school articulated to first and second years of postsecondary education? (Page 19+.)

Was the program developed to provide entry-level employment skills after the first two years of training? If so, in what occupations could students expect employment opportunities? (Page 19+.)

Was a basic course outline developed for both secondary and postsecondary programs? (Page 19+.)

Were recommended student prerequisites made? (Page 19+.)

Was a list of curriculum reference materials developed? (Appendix K.)

Was a list of necessary tools/equipment, to include current costs for the secondary and postsecondary programs, developed? (Page 19+.)

Was a line drawing of a recommended facility, to include minimum space and arrangement of equipment, developed? (Page 19+ and Appendix J.)

Was a job competency profile for secondary and postsecondary programs as developed by area business/industry representatives developed? (Page 13 and Appendix F.)

ACCOMPLISHMENTS

Both a mailed survey and a series of in-depth interviews were conducted with representatives from advanced-technology industries in the Austin area. Steering Committee members reviewed the results of this activity at the December 15, 1986 meeting.

After an Executive Committee discussion, a curriculum for Instrumentation and

Control (I&C) technicians was selected from four curricular development possibilities. The Committee's decision was based on a review of existing Austin Community College (A.C.C.) and Leander High School curricula, as well as projections about the jobs for graduates, and faculty/facilities delivery capabilities.

One of CORD's responsibilities in developing an Instrumentation and Control curriculum was to establish a list of job competencies from data gleaned from interviews and surveys, as well as competencies identified in former CORD projects.

The list of job competencies was mailed to eight Austin-area industry representatives who are knowledgeable about I&C technician jobs. Advisers responded by ranking the relative importance of the suggested competencies and making recommendations about any additional competencies they believed were needed.

The directives of these I&C advisers were compiled to form the basis for the curriculum design. CORD matched courses and course content to job competencies to be taught in the I&C curriculum and determined an initial selection of courses for the I&C curriculum. The resulting model curriculum was reviewed by the Steering Committee.

CORD analyzed the curriculum delivery system in light of current course offerings at Leander ISD and Austin Community College. The Executive Committee and CORD discussed a preliminary plan for curriculum delivery and articulation of coursework. Facilities and faculty for both Leander ISD and ACC also were discussed.

CORD staff met with Leander ISD representatives and discussed the competencies that must be taught in the courses offered at the secondary level. Discussion focused on how these courses would fit into the overall plan that high school students generally follow.

CORD staff also met with representatives from ACC and discussed the competencies taught in courses offered at the postsecondary level. Discussion centered on

which courses already existed, which courses currently taught at ACC could be substituted for the recommended curriculum, and which new courses needed to be developed from the course outlines prepared by CORD.

Members of the Executive Committee drafted an articulation agreement to be signed by representatives of both institutions.

The articulation plan was reviewed by members of the 2 + 2 Project Steering Committee during the presentation of the third quarterly report on June 15, 1987. Details of the articulation agreement will be delineated in a separate working document and revised by members of the Executive Committee as part of a yearly review process which will occur after each year of the program.

DEVELOPMENT OF THE LEANDER ISD/ACC 2 + 2

ARTICULATED CURRICULUM

THE PROCESS

The Texas Education Agency funded a project to set up a 2+2 articulation program between Leander Independent School District and Austin Community College. The general objectives identified for this project were to: (1) research the training needs for technical occupations in the Austin area, and (2) develop a statewide model for a 2+2 articulated education/training program in which students could develop the skills and abilities required for entering these occupations.

Leander ISD and ACC established a Project Steering Committee from area industries and educational institutions. (A list of the names and affiliations of the Steering Committee is given in Appendix A.) The Center for Occupational Research and Development (CORD) was selected to act as a consultant agency for the project. This selection was based on CORD's experience in developing model curricula in advanced-technology fields. CORD also has had experience in developing model curriculum for 2+2 articulated programs.

So that the articulation project could address the specific needs of the Austin area, businesses and industries operating in the Greater Austin area were identified. A broad, representative cross-section of businesses and industries was obtained by searching the 1986 Directory of Texas Manufacturers published by the University of Texas at Austin. Businesses were selected whose principal product and annual sales indicated they were likely to be potential employers of the graduates of the articulated program. As a result of this endeavor, 70 key industries and key personnel were identified.

CORD developed a questionnaire (See Appendix B.) that surveyed the "technician needs" of Austin area businesses. The survey instrument was designed to show the current and future technician needs for the Greater Austin area. In addition, the survey was designed to ascertain the acceptable level of

education/training for entry-level technicians. After approval of the survey instrument by the Steering Committee, the survey was sent to each of the 70 companies.

CORD also interviewed first-or second-line managers who were familiar with daily technican tasks, and who were closely involved in the process of selecting and interviewing technician applicants.

An interview instrument (See Appendix C.) was designed to measure the depths of knowledge and other skills required for entry-level technicians. The areas of knowledge included electrical/electronics, mechanical, fluid (pneumatic and hydraulic), thermal, optical, chemical, computers and sensors/instrumentation. The extent of need for communication skills, leadership skills, and interpersonal skills also was assessed.

Seven businesses and industries were visited, and 35 technician job descriptions were discussed. The job areas included electrical, electronics, chemical, metallurgical, test, environmental control, refrigeration, repair/maintenance technicians, and technical writers. For each job title, the business representative being interviewed was asked to indicate the depth of knowledge required by the entry-level technician in each of the broad areas of knowledge listed above. The depths were broadly categorized as either: (1) "cookbook"--type knowledge---that necessary to function by reading a manual, (2) "analytical"---the ability to analyze and remedy a situation not functioning normally, or (3) "creative"---the ability to perform adaptive or design-type activities. Within each of these broad categories, there were more descriptive terms to further pinpoint the depth of knowledge required for each field.

ANALYSIS OF DATA FROM MAILED SURVEYS

The mailed survey identified several technician types in the Austin area. The graph shown in Figure 1 summarized the mailed survey data.

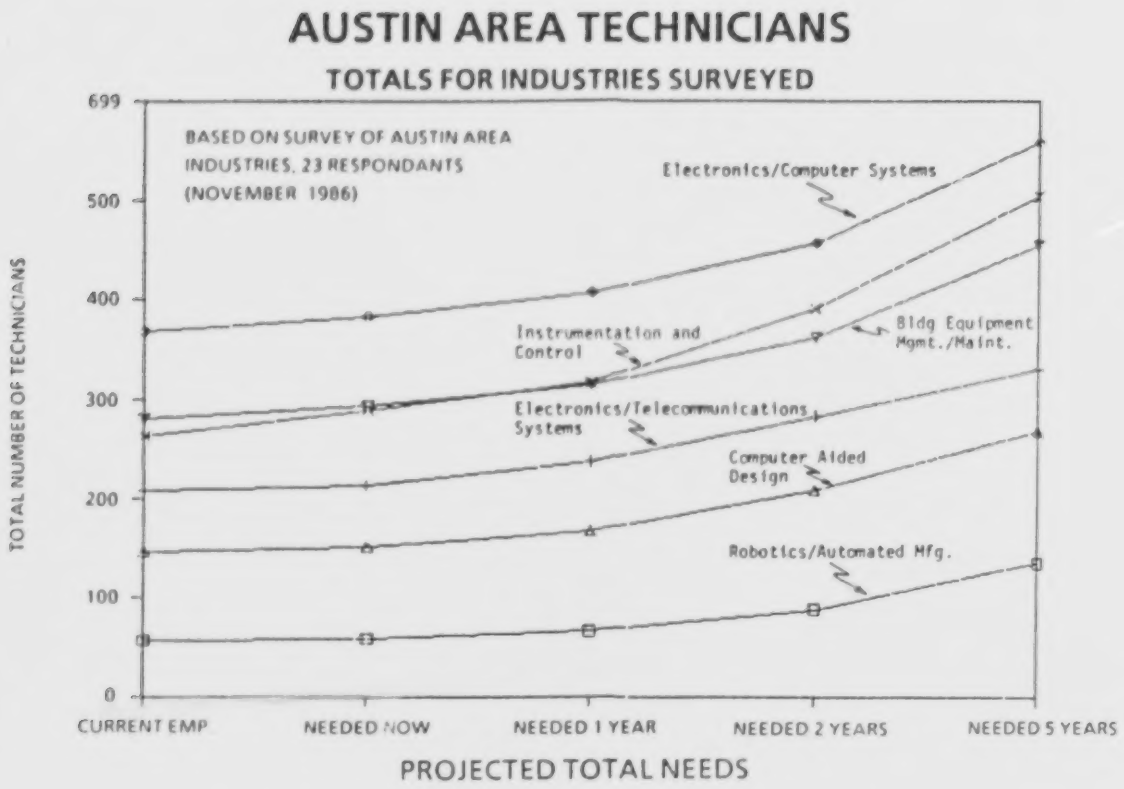

Fig. 1 Projected needs for Austin-area technicians.

The survey results also indicated that, for most of the businesses and industries responding to the survey, technician jobs currently are filled by persons having associate degrees. In addition, there was some reluctance to consider an applicant who has only a high school diploma.

ANALYSIS OF DATA FROM INTERVIEWS

The interview survey instrument facilitated comparing and contrasting the depths of knowledge required for the variety of positions represented in the Austin industries visited. Figure 2 showed a comparison of the depths of knowledge for the various types of technical occupations discussed. The chart showed a definite interrelationship of knowledge within each occupational field. For

example, each occupational area required knowledge of electrical systems---a depth of knowledge up to the point of being able to troubleshoot a piece of equipment. An electronics technician is required to have the greatest level of knowledge, but each of the other occupational areas also has required electronics knowledge. This relationship has indicated the need for a technical core curriculum that is capable of supporting several technical curricula. (Technical core curriculum is discussed in another section of this document.)

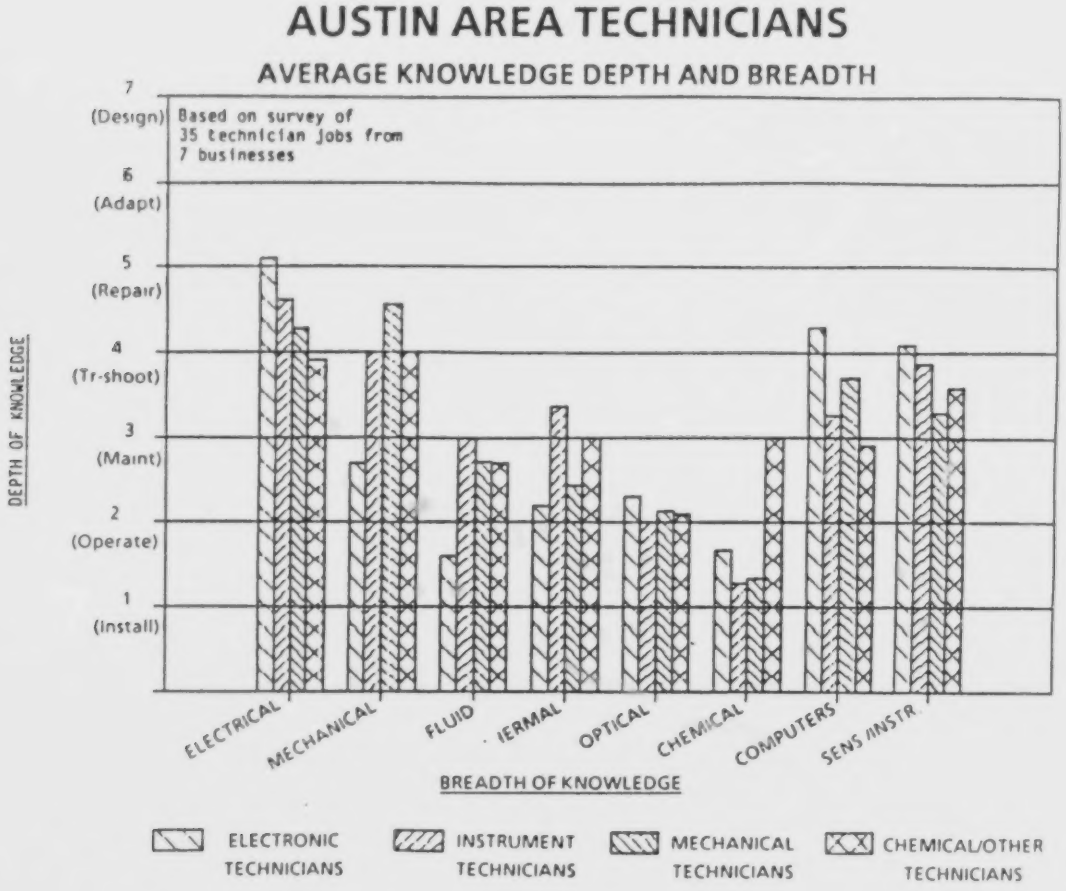

Fig. 2 Types of knowledge required by technicians.

DATA ANALYSIS CONCLUSION

The data-gathering phase indicated that business representatives are willing to provide input and cooperate in identifying the types of knowledge required in

technical occupations. Data showed that a "2+2" articulated curriculum graduate should be employable in the Greater Austin Area. Based on surveys, interviews with industry representatives, and a review of the program and facilities capabilities of Leander I.S.D. and ACC, the Steering Committee chose Instrumentation and Control for curriculum development.

TYPICAL INSTRUMENTATION AND CONTROL TECHNICIAN JOB DESCRIPTIONS

Generally speaking, today's I&C technician does a great deal more than the narrowly defined role he or she may have had in the past. Both the role and industry areas have changed.

Usually, I&C technicians in the Austin area have worked in process-control industries. Some technicians have worked mainly with instrumentation. For others, the technician's job has involved both instrumentation and control. I&C jobs are available in manufacturing, research and development activities, processing industries, electrical power plants, etc. Almost certainly, some future I&C technician jobs will be in the emerging biotechnology industry.

Some examples of I&C occupations in Austin are:

Advanced Micro Devices

The principal product at AMD is silicon wafers containing the microscopically formed chemical patterns destined to become integrated circuits. I&C technicians are responsible for the strict environmental control required of such a manufacturing process. In addition, the processing equipment requires stringent regulation of temperatures, pressures, and gas flows. The I&C technician is frequently called upon to modify equipment to obtain the desired conditions. Diversified knowledge and hands-on experience are invaluable traits for I&C technicians at AMD.

Center for Electromechanics

I&C technicians at the Center for Electromechanics are deeply immersed in research and development. Performing high-energy and power experimentation, the technician must set up and sometimes even design the instrumentation that will monitor and control the process under study. When an experiment lasts only a fraction of a second and costs thousands of dollars to perform, proper data acquisition and process control are imperative.

Radian Corporation

Monitoring the environment is important to the Radian Corporation. Radian I&C technicians perform a vital role in that task by installing, operating, and maintaining the instrumentation that performs the function of air monitoring. Both electronics and pneumatic processes are involved. In addition, these technicians must be capable of analyzing the information obtained by their instrumentation, finding and correcting equipment problems as they occur, and reporting on the data obtained.

City of Austin, Power Generation Division

The I&C technicians working the Power Generation Division are closely attuned to the interrelated operation of the boilers and turbines; because these technicians maintain the controls and auxiliaries that are responsible for the successful operation of the power facility. A variety of thermocouples, flowmeters, and pneumatic, electronic, and hydraulic control systems all come within the scope of responsibility of the I&C technician working for the City of Austin's Power Generation Division. In addition, computers have played an important role in energy management, and these technicians are involved with the data acquisition for a database of the various plant conditions.

3M Corporation

One of the 3M Corporation divisions in Austin is the TelCom Products Division. TelCom tests telecommunications-related products produced by 3M. I&C technicians at TelCom set up and control accelerated aging tests that simulate

environmental conditions such as chemical erosion, mechanical fatigue, and weathering. Test equipment used at TelCom is controlled by pneumatics, hydraulics, mechanics, electronics, and electromechanics.

Although job descriptions for I&C technicians vary, a general description might be as follows:

> I&C technicians are technical specialists who have interdisciplinary skills in the use of microprocessors and electronic, mechanical, hydraulic and pneumatic devices in control systems. They are able, independently, to test, troubleshoot, repair, fabricate, assemble and adapt control system components. They understand the role of microprocessors and sensing devices in simple or complex control loops. They are entry-level technicians who may work under the supervision of senior technicians or engineers, and who often assist and train other technicians.

I&C technicians are employed in various industries. Job titles have included, among others, the following:

Instrument Repairer	Instrument Mechanic
I&C Sales and Service Representative	Process Technician
Customer Engineering Technician	Process Control Tech
Electromechanical Technician	Instrument Technician

A RATIONALE FOR THE CORE CURRICULUM APPROACH TO PREPARE TECHNICIANS FOR AUSTIN INDUSTRIES

Technology's continued advancement depends on a critical factor--- the expeditious use of human resources. Today's work force must be trained---and retrained---to adapt to change. A core curriculum approach seems the best vehicle for providing this training. (Hull, Daniel M. and Pedrotti, Leno S.

"Challenges and Changes in Engineering Technology." Engineering Education (May, 1986): 726-732.)

Core curriculum design is not new. However, prior to 1980, few schools had technician training programs that emphasized the broad-based approach. Instead, prior training programs tended to focus on a narrow range of specialty skills that led to specific careers. This scene is changing during the '80s, principally because today's work force is being impacted by technological change. The result of this change has been a shifting work force structure that is evidenced by layoffs and reallocation of human resources. In summary, broad-based core curriculum with specialization in a given area will best prepare technicians for today's work force.

A broad-based, systems-oriented curriculum has two parts. These two parts are (1) the common core, and (2) the specialty area. (See Figure 3.) The common core contains the courses that technicians should take--no matter what their occupational area. This common, or universal, core has included two levels: (a) the "basic" skills and (b) a "technical core." The basic skills courses have included what employers and educators consider to be the "survival skills" necessary for technicians.

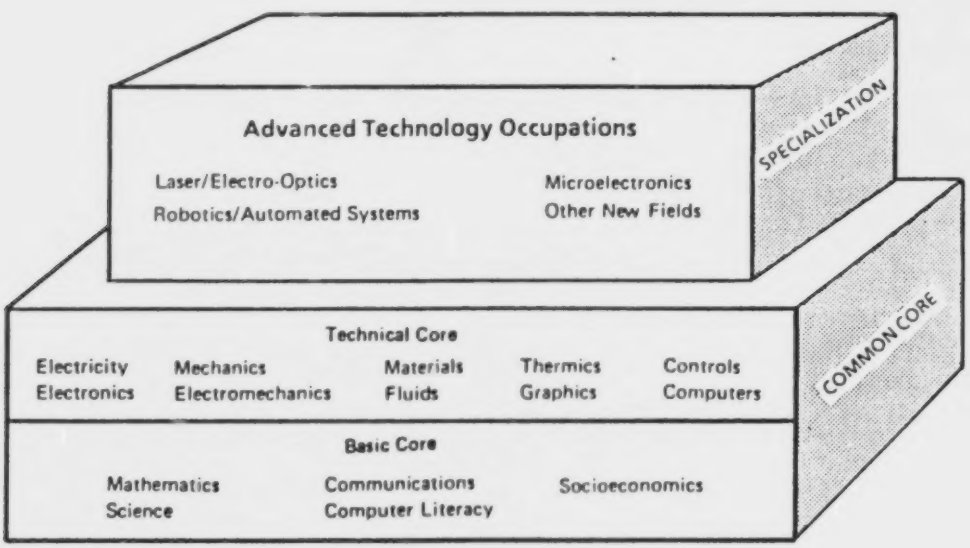

Fig. 3 Broad-based curriculum for advanced-technology occupations.

The second level of the common (or universal) core has contained the "technical core" courses. These courses will transfer the skills that a technician must master, whether employed in laser/electro-optics, robotics, or microelectronics--in other words, any of the advanced-technology fields that build on a "core" of technical information.

In the core curriculum approach to training, the aspiring technician will follow the "common core"---or base of training---with courses in a specific field. "Specialty" courses have addressed "special" competencies not covered in other courses. Specialty courses have provided the technician with the specialized information needed to succeed in a given field---telecommunications, lasers, computers, robotics/automated manufacturing, etc.---and also have reinforced previously taught information at a "higher" level of training.

It was the broad-based approach---capped by a specialty area--- that has ensured career flexibility when workers must be retrained because of shifting job performance tasks or job obsolescence. When retraining must occur, it has only been necessary to retrain or update skills in the top-end specialty area.

In the Leander ISD/ACC 2+2 articulation project, the specialty field selected for curriculum development was the career path called "Instrumentation and Control." This decision was made as a consequence of the demand for I&C technicians indicated by surveys and interviews. The surveys indicated that the demand for I&C technicians in the Austin area is projected to be consistently strong during the next five years.

DEVELOPMENT OF THE CURRICULUM COMPONENTS FOR I&C TECHNICIANS

Based on CORD's experience in the development of other technical curricula, and from input obtained through both the mailed and on-site interviews, CORD developed a list of competencies of over 125 specific, job-related skills for I&C technicians. These competencies have formed the basis for the justification of courses in the I&C curriculum. The competencies are specific, identifiable, and measurable.

Industries were contacted who indicated an existing or growing I&C technician work force. Representatives were identified who were familiar with the tasks performed by their company's I&C technicians. These individuals covered a broad spectrum of industry expertise. The representatives served as advisers for validating the list of job competencies for I&C technicians. (A list of the advisers' names is given in Appendix D.)

For each suggested competency, the validators were asked to state whether the job task or knowledge was essential ("Must Know"), convenient ("Nice to Know"), or unnecessary ("Don't Need to Know"). Additional competencies, which may have been overlooked during the creation of the list, were solicited. The advisers were asked to evaluate only those competencies with which they were familiar. The competency validation form is given in Appendix E.

Returned validations were tallied. Validation rankings turned in by the advisers were found to be consistent. Some validations were observed, but since the areas were not pivotal to course inclusion or exclusion, a meeting of the validators to resolve these points was deemed unnecessary. Eighteen competencies were rejected with the validators indicating them to be unnecessary skills for Austin-area I&C technicians.

Potential I&C specialty courses and common core courses were identified. The competencies addressed by these courses were compared to the list of validated competencies for Austin-area I&C technicians. Identification with a course was obtained for each validated competency. Competencies used in establishing curriculum courses were those deemed by the advisers to be "essential" or "convenient."

Most of the identified competencies were terminal objectives in the "specialty area" skills. Hence, most criteria was satisfied by specialty courses. The nonspecialty skills were addressed by either the technical core or basic skill courses. In addition, the technical core courses will provide prerequisite skills and knowledge for the specialty courses.

This process of curriculum development has been illustrated in Figure 4.

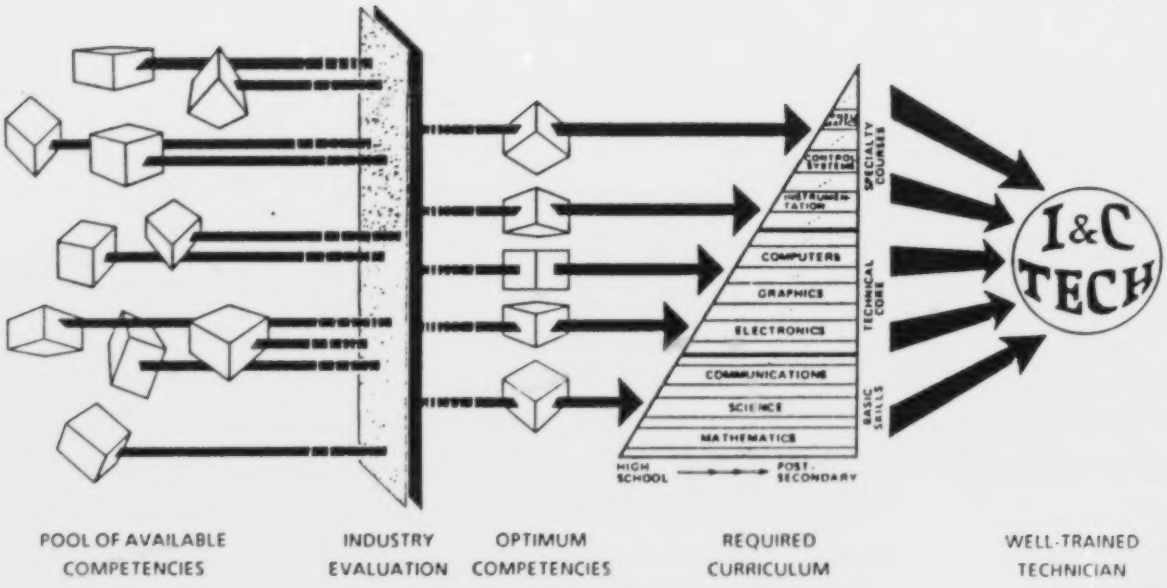

Fig. 4 I&C curriculum development process.

Other types of competencies were frequently mentioned by employers during the interviews. These competencies were related significantly to the success of technicians on the job. They were:

(1) Team Playing

(2) Teaching/Learning Attitude

(3) Communication Skills

(4) Creativity

(5) Leadership Skills

(6) Commitment to One's Ongoing Education

(7) Experience with the Company.

Such factors are often not listed as competencies because it is difficult to link them to specific, identifiable, measurable technical tasks. However, these

competencies are addressed within the curriculum by such courses as Industrial Relations, Technical Communications, and Economics in Technology.

CONVERTING VALIDATED COMPETENCIES TO INSTRUMENTATION AND CONTROL CURRICULUM

Appendix F showed the matrix used for correlating job competencies with Leander Independent School District and Austin Community College course content. Competencies were listed down the left side of the matrix; courses that make up an I&C curriculum were listed across the top of the matrix. Indicators were placed on the field of the matrix to show which competencies were satisfied by which courses. The competencies functioned as a "competency profile" for the I&C curriculum.

ARTICULATED CURRICULUM DEVELOPMENT

Appendix G can be a guide for developing a 2+2 curriculum that can be articulated between secondary and postsecondary schools. A chart of the articulated curriculum between Leander ISD and ACC has been shown in Figure 5. It designated the articulated I&C curriculum courses delivered at Leander ISD and the courses delivered at ACC. Course outlines for the I&C curriculum have been given in Appendix H.

Leander High School students must meet several prerequisites for entering the articulated curriculum. All sophomore students at LHS must take the Career Ability Placement Survey (CAPS) test and must score at least 22 in the areas of Technology. Algebra I shall be a prerequisite or corequisite to Principles of Technology; and the DC/AC Electricity courses will be prerequisites to the SemiConductor course.

Students successfully completing the I&C courses offered at Leander High School will acquire entry-level skills for employment positions such as a Test Operator, Electronic Assembler, Process Control Operator, and Manufacturing

Assembler (microcomputer products).

ARTICULATION AGREEMENT
FOR
INSTRUMENTATION AND CONTROL TECHNOLOGY
ASSOCIATE DEGREE

LEANDER HIGH SCHOOL				AUSTIN COMMUNITY COLLEGE				
JUNIOR		SENIOR		FRESHMAN		SUMMER	SOPHOMORE	
Principles of Technology I		Principles of Technology II			Applied Physics (Class) (4/0/4)		English Composition (1613)	Technical Communications (1633)
Geometry or Algebra		Semiconductors		Applied Math I (Algebra) (1743)	Applied Math II (Electronic) (2123)		Property of Material (2/0/2)	Economics in Technology (2/0/2)
D.C. Electricity (1148)	A.C. Electricity (1148)	Graphics	Computer Basics	Pulse Digital Electronics (2084)	Advanced Linear (2104)	Digital Logic (2094)	Microprocessors I (2114)	Microprocessors II (2214)
				Mechanical & Fluid Power Systems (2/4/4)	Industrial Electrical Power & Equipment (3/4/5)		Texas Government (2023)	Industrial Relations (2/0/2)
				Fundamentals of I&C (3/4/4)	Industrial Electronics (2164)	Control Systems (3/4/5)	Analytical Instrumentation (2/4/4)	

Figure 5 Articulation Agreement

Students enrolled in and successfully completing the secondary portion of the 2 + 2 articulated curriculum are granted ACC "credit in escrow." This means that when students enroll in, and complete, the first six hours of coursework at ACC, they will be granted 12 hours of additional college credit. Appendix I has given the recommended plan for allowing students, who have not participated in the 2 + 2 plan, to enter the I&C major at ACC.

Appendix J has provided guidelines for developing lecture and laboratory facilities. The accompanying drawing illustrated the minimum recommended area (room size) for each I&C course. Each laboratory area, based on a class size of 12, included space for equipment storage, lab activity, and a lecture/demonstration activity. Depending on course scheduling, several lecture and laboratory areas can utilize the same facility. For example, the Geometry class can be taught in the same classroom facility. Similarly, the Physics class can be taught in the same laboratory area.

Currently, the average cost of a turn-key package for Principles of Technology could be $16,000. per lab station. CORD'S analysis of equipment for the DC Electricity, AC Electricity, and SemiConductor courses indicated that the equipment cost for the group of courses was approximately $1,400. per lab station.

Reference materials for the I&C courses are given in Appendix K. Many of the listed texts currently are being utilized by Leander ISD and ACC.

SUMMARY FOR THE 2 + 2 ARTICULATION PROCESS

In summarizing the year's grant progress, it was important to note that the success of this articulation plan between secondary and postsecondary was dependent upon answering the needs of the area business and industries. Very few articulation agreements will be successful if they do not fulfill the needs of the area businesses and industries. Students graduating from the secondary and, later, the postsecondary institutions will have developed skills that are marketable and saleable if these needs are heeded.

This process began with a feasibility study of the area businesses and industries and a request for input of their specific needs. Once those needs were identified through the feasibility study, questionnaires, and on-site interviews, the secondary and postsecondary entities formulated their curricula and the initial costs of the program starts. The detail of these course outlines, essential elements, and per item course costs will be handled in the second part of the grant endeavor to be finalized in 1988.

Another key to success in formulating an articulation agreement is the cooperation between the secondary and postsecondary levels from the boards of trustees, the administrations, and the faculties involved. Each of these entities should be kept informed and given opportunities for input into the entire process. These groups, as well as the businesses and industries of the area, should be given frequent opportunity for input and reaction as the articulation process develops because each has a different and valuable perspective of the expectations and needs for the adults and students at all

levels. The details of the entire process from the beginning to the general outline of the articulation program are embodied in this final report and again the emphasis will be on the cooperation between groups for success.

Articulation Agreement
Leander ISD / Austin Community College

What Is Articulation?

Articulation is an agreement between public schools and postsecondary institutions which may allow a student to receive credit for instruction received while attending public schools.

Statement of Intent

The purpose of this Articulation Agreement is to provide a mechanism through which vocational/technical education programs at the secondary and postsecondary levels will interface, thereby granting students who have mastered agreed-upon task competencies at the secondary level college credit for similar task competencies in vocational/technical programs at Austin Community College.

Who Is Eligible?

Any student who has attended an articulated program in a public school which has signed an agreement with Austin Community College may receive credit for instruction received.

Procedures

1. Students applying for advanced-placement credit through Leander ISD/Austin Community College Two-Plus-Two Articulation plan must expect to graduate from a participating program in a school district that is a member of the project.
2. Students should apply for postsecondary credit at the time they make application for admission to the college and a student must enroll at ACC within five years after high school graduation in order to be eligible for college credit under this agreement. If the time limit has expired, the student may choose to take competency examinations.

3. After the applicant for postsecondary credit successfully completes at least six credits of course work in residence at Austin Community College (not counting independent study, cooperative education, internship or practicum courses), he/she will be notified by the registrar that his/her request for credit has been granted. At that time, such credit will also be duly recorded on the student's academic record. (Students with at least six credits of prior resident credit at ACC will be granted postsecondary credit immediately upon proper application and payment of the administrative fee.)
4. All new full-time faculty and administrators directly involved in the articulation agreement will be in-serviced in the articulation plan.
5. Equivalency credits for articulated courses will become part of the total number of credits required for program completion and will appear on the ACC transcript by course title and credit hour(s).
6. The maximum amount of postsecondary credit will vary by program area.
7. The student who elects to participate in the Two-Plus-Two Plan will be counseled at the secondary and/or postsecondary levels about the career goal options available to him/her.

Articles of Agreement

1. All articulating students will meet and maintain all entrance standards, prerequisites, and academic standards of the postsecondary institution and intended program of study.
2. Successful completion of the secondary portion of the Two-Plus-Two Plan will become part of the student's permanent record and will be forwarded to the postsecondary institution upon request by the student.
3. Tuition will not be charged for courses for which the student receives credit from the secondary institution.
4. Credit granted for articulated competencies will appear on the transcript of the institution granting the credit.

5. Articulation Agreement Review and Change:

   5.1 At the end of the academic year, a review of the Articulation Agreement and process will be conducted. All superintendents, secondary principals, and occupational administrative personnel will be invited to provide input for review and revision.

   5.2 At the end of the academic year, all teachers of secondary and postsecondary occupational programs and industry representatives will be invited to provide input for review and revision of the tasks and tests.

Participating Institutions and Curriculum Areas

This agreement will become effective upon approval by the president of Austin Community College and the superintendent of Leander ISD. Upon implementation, this agreement will continue on an annual basis until one of the parties petitions the other party to end the agreement.

Such petition to end this agreement: (1) must be submitted one year in advance of the intent to terminate; (2) must be submitted in writing, signed by the college president or school superintendent making the petition; and (3) must be delivered to the second party to the agreement. Delivery of the intent to terminate will constitute formal notification and will serve as grounds for termination one year following the date of delivery.

Authorized Agent for Austin Community College	Authorized Agent for Leander ISD
10-22-87 Date	10-20-87 Date

APPENDIX A

Steering Committee

LISD/ACC STEERING COMMITTEE

Name and Addresses	Telephone No.
BUSINESS AND INDUSTRY NAMES:	
Mr. Allen Boger 3M Corporation Building 502 11209 Metric Blvd. Austin, TX 78769-2963	512-834-1800
Mr. Chuck Bradley Cost Center Mgr., Unit Listing Mail Station 2092 Texas Instruments 12337 Technology Blvd. Austin, TX 78727	512-250-6753
Mr. James Cannan Technical Electronic Engineer Semiconductor Products Sector Mail Drop K-4 Motorola, Inc. 3501 Ed Bluestein Blvd. Austin, TX 78721	512-928-7585
Mr. Leroy Kana Vice President, Product Assurance Tracor, Inc. 6500 Tracor Lane Austin, TX 78725	512-929-2508
Mr. Robert Mann Senior Scientist Radian Corporation 8501 Mopac Blvd. Austin, TX 78759	512-454-4797

Mr. George Matott — 512-250-7422
Employee Education Center Manager
Mail Station 2001
Texas Instruments
12501 Research Blvd.
Austin, TX 78769

Mr. Jim O'Connor — 512-386-1597
Director of Manufacturing, Austin Div.
Lockheed Missiles and Space Company
6800 Burleson Rd.
T3-30, Bldg. 312
Austin, TX 78744

Mr. John Rundell — 512-838-1557
Senior Education Specialist
IBM Corporation
11400 Burnet Road
Austin, TX 78758

Mr. Robert Schweter — 512-469-7114
Test Supervisor
Mail Station 210
Rolm Corporation
2420 Ridgepoint Drive
Austin, TX 78754

Mr. Ron Smith — 512-834-3102
Mgr. Human Resource Administration
3M Corporation
2120 P West Braker Lane
Austin, TX 78769

Mr. Walter Stone — 512-288-1453
Director of Manufacturing
KMW Systems Corporation
8313 Highway 71 West
Austin, TX 78735

EDUCATION AND RELATED PERSONNEL:

Mr. James Cogdell — 512-463-9446
Director, Trade and Industrial Education
Texas Education Agency
1701 North Congress
Austin, TX 78701

Mr. Norm Colbath — 512-495-1675
Electronics Dept. Head
Austin Community College
205 E. 5th Street
Austin, TX 78768

Ms. Linda Hanson Gray — 512-259-1113
Assistant to the Supt.
Leander Independent School District
401 S. West Street
Leander, TX 78641

Mr. Joe Keener — 512-259-1198
Teacher, Leander High School
Leander Independent School District
3301 S. Bagdad Rd.
Leander, TX 78641

Mr. Mark Kincaid — 512-259-1198
Teacher, Leander High School
Leander Independent School District
3301 S. Bagdad Road
Leander, TX 78641

Mr. Bert Marcom — 512-495-7579
Dean of Vocational and Technical Education
Austin Community College
205 E. 5th Street
Austin, TX 78768

Mr. Jack Patterson 512-495-1680
Chairperson, Technical/Industrial Div.
Austin Community College
205 E. 5th Street
Austin, TX 78768

Ms. Maggie Rice 512-259-4201
Curriculum Director
Leander Independent School District
401 S. West Street
Leander, TX 78641

Mr. Jack Risinger 512-463-9688
Assistant Director, Trade and Industrial Ed.
Texas Education Agency
1701 North Congress
Austin, TX 78701

Mr. Mike Roarke 512-462-6300
Program Director
Community Colleges and Technical Institutes
Texas College and University Coordinating Board
200 E. Riverside
Austin, TX 78704

Mr. Charles Rouse 512-259-1198
Principal, Leander High School
Leander Independent School District
3301 S. Bagdad Road
Leander, TX 78641

Ms. Meg Wilson 512-463-1796
Coordinator, Center for Technology
Development and Transfer
ECJ 2.516
University of Texas at Austin
Austin, TX 78712

Appendix B

Questionnaire and Cover Letter

November 21, 1986

Dear :

You are part of a carefully selected group of Austin industry representatives who are being asked to complete a survey of employment needs. Your answers will help determine the content and direction this curriculum will take.

Austin Community College and Leander Independent School District are working together to prepare new technical employees for the workforce that serves Greater Austin industries.

A program to identify an effective education/training plan for system technicians is being funded by the Texas Education Agency. A description of this program is enclosed. The Center for Occupational Research and Development (CORD) is providing coordination and technical assistance to the two schools involved in this endeavor. We need your help.

Please assist us by completing the attached questionnaire and returning it to CORD A.S.A.P. Our survey results must be in final form by the end of this month.

If you would like to receive the results of the survey and more information about the progress of the project, please tell us.

Thank you for your time.

Sincerely,

Casanda Burleson Jordan
Research Associate
CORD's 2 + 2 Project Coordinator

Sincerely,

Linda Hanson
Assistant to the Superintendent
2 + 2 Project Coordinator
Leander Independent School Dist.

CBJ/pt
Enc.

AUSTIN COMMUNITY COLLEGE / LEANDER SCHOOL DISTRICT
SYSTEM TECHNICIAN NEEDS IN AUSTIN
Questionnaire

Please return this questionnaire to:

Cassy Burleson Jordan
CORD
601 C Lake Air Drive
Waco, Texas 76710
817/772-8756

If you wish to know the results of this survey, please indicate below.

( ) Yes, please send me information about the results of this survey.

( ) Please send me more information about the overall 2+2 program.

■ ■ ■

7. What is the level of education/training for your current employees in the career paths listed above? (You may use the appropriate letter to identify the career path.)

Career Path	Education		Additional Training
	High School	2-Year Postsecondary	
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

8. At what educational level would you hire an applicant in any of the categories described in Item 6. (You may use the appropriate letter to identify the career path.)?

High School Grad	A.S. (2-Year Postsecondary Degree)	Career Path
_____	_____	_____
_____	_____	_____
_____	_____	_____

9. Would you be willing to serve on a program advisory committee? _____

For which career path? _____

_____

_____

10. Additional comments _____

_____

_____

_____

_____

_____

Appendix C

Interview Guide

"2+2" Interview Guide

****

Objective of Interview:

To determine required competencies for entry level industrial technicians in Austin area in order to be able to recommend a technical core curriculum for the LISD/ACC "2+2" articulation program.

****

I. Introductions and Opening Comments

A. Persons and level of management involved in interview (should be second line managers, or similar, depending on size of organization)
B. Statement of objective for interview
C. Schedule for day's interviews and activities

II. Plant Tour, if possible

A. Nature of operation/business
B. Employees: management, skill levels, numbers of, responsibility level, interaction skills
C. Equipment: sophistication, automation, environmental restrictions, throughput, maintenance requirements, support requirements e.g., air, steam, etc.)

III. Interview process

A. Types of technologies in equipment
B. Types of technicians
C. Equipment knowledge required by technicians
D. Numbers of technicians required
E. Specialized training required
F. Job descriptions for technicians
G. Future needs (upgrading, new equipment, new hiring/expansion)

AREAS OF COMPETENCY

What is that you need in this technician? Company: _____

JOB TITLE: _____

JOB DESCRIPTION: _____

_____

OVERALL JOB DEPTH:	******* First Level *******			** Second Level **		***** Third Level ******	
	1	2	3	4	5	6	7
(Breadth\Depth) SYSTEMS\AREAS	INSTALL	OPERATE	MAINTAIN	TR-SHOOT	REPAIR	ADAPT/MODIFY	DESIGN
A. Electrical	-------	-------	-------	-------	-------	-------	-------
B. Mechanical	-------	-------	-------	-------	-------	-------	-------
C. Fluid (Pneu/Hydr)	-------	-------	-------	-------	-------	-------	-------
D. Thermal Devices	-------	-------	-------	-------	-------	-------	-------
E. Optical	-------	-------	-------	-------	-------	-------	-------
F. Chemical	-------	-------	-------	-------	-------	-------	-------
G. Cmputr/ProcCntrlr	-------	-------	-------	-------	-------	-------	-------
H. Sensors/Instrm	-------	-------	-------	-------	-------	-------	-------

I. Communication Skills _____

J. Leadership Skills _____

OTHER COMMENTS (Use letters/numbers above to reference)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Appendix D

Advisors

ADVISORS OF COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS

Mr. Allen Boger
3M Corporation
11209 Metric Blvd, Bldg 502
P.O. Box 2963
Austin, TX 78769-2963

Mr. Bob Bolander
Mail Drop OE21
Motorola Inc.
6501 William Canon Drive West
Austin, TX 78735-8598

Mr. John Caffall
Supervisory Process Engineer
Advanced Micro Devices
5204 E. Ben White Blvd
Austin, TX 78741

Mr. John Gossard
3M Corporation
11209 Metric Blvd, Bldg 502
P.O. Box 2963
Austin, TX 78769-2963

Mr. John Gully
Center for Electromechanics
Balcones Research Center
10100 Burnet Road
Austin, TX 78758

Mr. Scott Jenkins
Radian Corporation
P.O. Box 9948
Austin, TX 78766

Mr. Paul Mix
Design Engineer
Texas Nuclear Corp.
P.O. Box 9267
Austin, TX 78767

Mr. Don Shafford
Power and Generation Division
City of Austin
P.O. Box 1088
Austin, TX 78767

Appendix E

Competency Validation

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
1				Analyze, construct, and/or troubleshoot:
	𝍸 ///			a. Series-parallel circuits
	//	/		b. Bridge circuits
2				Analyze, construct, and/or troubleshoot; series, parallel, or complex:
	𝍸 ///			a. Resistive-inductive-capacitive (RLC) circuits
	𝍸 //	/		b. Resonant circuits
	𝍸 //	/		c. Filter circuits
	𝍸 //	/		d. Polyphase circuits
	𝍸 //	/		e. Amplifiers and equalization networks
3				Set up instrumentation and measure a given voltage, current, resistance, power, and/or frequency using the appropriate equipment:
	𝍸 ///			a. Volt-ohm-milliammeter (VOM)
	𝍸 ///			b. Digital multimeter (DMM)
	𝍸 //	/		c. Frequency counters
	𝍸 //	/		d. Signal generators
	𝍸 /	//		e. Capacitor-inductor analyzers
	𝍸 ///			f. Impedance bridges
	𝍸 ///			g. Oscilloscopes
	𝍸 //	/		h. Sweep generators
	𝍸 /	//		i. Spectrum analyzers
	𝍸 //	//		j. Cable-fault analyzers
4	𝍸 ///			Read and sketch electronic schematics.
5	𝍸 ///			Record data and design curves and graphs.
6	//	///	/	Build and test interfaces between transistor-transistor-logic (TTL) and complementary metal-oxide semiconductor (CMOS) circuits.
7	////	////		Explain the role of timing in communication; distinguish between synchronous and asynchronous transmission.
8	𝍸	𝍸 //		Identify microcomputer integrated circuits (IC) and determine function and logic from manual.
9	𝍸 //	𝍸 ///		Use logic analyzer for dynamic testing of microcomputer systems.
10				Calibrate or check calibration of:
	////	///		a. Test instrument meters
	///	////		b. Frequency counters
	///	////		c. Spectrum analyzers
11	////	////		Describe and demonstrate multiplexing and demultiplexing.
12	////	////		Describe how to recognize static electricity problems and how to rectify them.

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
13				Construct, troubleshoot, repair, and/or replace the following:
	////	//		a. Series-parallel circuits
	////	//		b. Voltage-divider circuits
	////	/		c. Resistive-inductive-capacitive (RLC) series/parallel resonant and filter circuits
	////	//		d. Polyphase circuits
	////	/		e. Diode circuits
	////	/		f. Single- and multi-stage amplifiers
	////	/		g. Power supply circuits, regulated and unregulated
	////	/		h. Active filter circuits
	////	/		i. Oscillator circuits
	////	/	/	j. Motor or phase-control circuits
	////	/		k. Logic gates
	////	/		l. Flip-flops
	////	/		m. Registers and counters
	////	/		n. Clock and timing circuits
	////	///		o. Logic arithmetic circuits
	////	///		p. Encoders and decoders
	////	//		q. Multiplexers and demultiplexers
	////	//		r. Memory devices
	////	///		s. Analog-to-digital (A/D) and digital-to-analog (D/A) circuits
	////	//		t. Displays
	////	//		u. Representative digital systems
14	//	////	//	Describe capacity of a communications channel in terms of bandwith and baud-rate.
15	//	////		Describe communication made possible by simplex, half-duplex and duplex links.
16	/	/	////	Build a digital and an analog multiplexed data communication system; use each system to communicate information.
17	Part to #8			Identify integrated circuits (IC) and determine function and logic from manufacturer's data sheet.
18	////	////	///	Locate source of static difficulties in small microcomputer hardware.
19	Part to #9			Use logic analyzer for dynamic testing of microcomputer systems.
20	//	////	/	List the precautions and the general procedures/steps taken in device transportation and installation.
21				Write programs in one of the following languages:
	////	///		a. BASIC
	//	////	/	b. FORTRAN
	/	////	//	c. PASCAL
	/	///	///	d. Machine languages
	/	////	/	e. Assembler languages
	/	////	/	f. MS-DOS
	/	////	/	g. C
22	////	////		Program or reprogram erasable/programmable ROM (EPROM).
23	////	///		Repair data-storage equipment, and interface controllers.

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
24				Align, analyze, troubleshoot, and repair and return to service:
	////	////	/	a. Display terminals
	////	////	/	b. Interface controllers
	////	////	/	c. Printers
25				Define computer acronyms.
	//// //	/		a. RAM
	//// //	/		b. ROM
	//// //	/		c. DOS
	//// //	/		d. CRT
	//// //	/		e. MODEM
	//// //	/		f. dma
	//// //	/		g. IC
	//// //	/		h. CPU
	//// //	//		i. EPROM
26	////	///		Load, run, and understand operating system software.
27	/////	////		Load, run, and understand diagnostic software, both local and remote.
28	/////	///	/	Construct and analyze flow charts.
29	//	////	/	Identify and define computer languages and their uses.
30				Identify, define, and analyze:
	///	///	/	a. Synchronous devices
	///	///	/	b. Asynchronous devices
	//	////	/	c. Packet switching
31	//	//	///	Identify, define, analyze, and troubleshoot protocols.
32	/	//	////	Identify and define networking levels or layers.
33	//	////	/	Recognize, identify, isolate, and remedy sources of electromagnetic radiation (EMI), radio-frequency interference (RFI), and static electricity.
34	/	///	///	Make and repair fiber-optic cable splices.
35	/	//	////	Diagnose, repair, and return bar-code readers to service.
36	////	///		Demonstrate good, considerate, conscientious customer relations skills.
37	//// /	//		Use diagnostic hardware, firmware, and/or software.
38	//// /	//		Solder and desolder CMOS devices.
39	/	//	///	Diagnose and correct protocol problems.
40				Identify and explain the operating principles of each instrument that measures:
	//// /	//		a. Pressure
	//// /	//		b. Liquid level
	//// /	//		c. Temperature
	//// /	//		d. Flow

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
1				For a given application, specify the range, accuracy and type of instrument which measures:
	////	////		a. Pressure
	///	////		b. Flow
	////	////		c. Temperature
	////	////		d. Liquid level
2				Calibrate instruments used in measurement of:
	~~////~~	//	/	a. Pressure
	~~////~~	//	/	b. Liquid level
	~~////~~	//	/	c. Temperature
	~~////~~	//	/	d. Flow
43	///	////	/	Demonstrate use of various differential pressure-sensing flowmeters.
44	//	////	//	Sketch a typical differential-pressure flow-sensing device and transmission channel.
45	/	///	/	Install an orifice plate and venturi tube in pipes; measure pressure drops as functions of flow; calculate flows,based on nominal discharge coefficients, for each device.
46	//	//	/	Calibrate an orifice plate and venturi tube by making a differential-pressure versus flow curve; calculate discharge coefficient.
47				Measure temperature using the following types of electrical temperature measuring devices:
	~~////~~//	/		a. Thermocouple
	~~////~~ //	/		b. RTDs
	////	////		c. Optical
8				Operate each of the following devices:
	///	//	/	a. Linear potentiometer
	///	//	/	b. Rotary potentiometer
	///	//	/	c. Linear inductor
	///	//	/	d. Rotary inductor
	///	//	/	e. Linear variable differential transformer (LVDT)
	//	//	//	f. Synchromechanism
	///	/	//	g. Flyball governor
	///	//	/	h. Strain gage
9				Make measurements of linear and angular displacement, velocity and force with:
	//	///	/	a. Linear potentiometer
	//	///	/	b. Rotary potentiometer
	//	///	/	c. Linear inductor
	//	///	/	d. Rotary inductor
	///	///	/	e. Linear variable differential transformer (LVDT)
	/	///	/	f. Synchromechanism
0	//	///	/	Bond a series of strain gages to a solid steel cylinder; hook up gage as part of a measurement bridge and determinethe characteristics of the homemade load cell.
1				Use a pneumatic transmitter in a system to measure the following variables:
	//	///	/	a. Temperature
	///	//	/	b. Level
	///	//	/	c. Flow
	///	//	/	d. Pressure

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
52	//	//	//	Calibrate and align a pneumatic transmitter.
53				Implement the operation of a closed-loop control system by performing the following:
	///	//	/	a. Install closed-loop control components on a combination level-flow process.
	///	//	/	b. Connect the instruments to perform closed-loop control function.
	///	//	/	c. Make instrument adjustments to provide optimum process control. Include controller tuning, transmitter range selection, and adjustment.
54				Identify a method of quality control evaluation and relate the effect each control-loop component on the quality ofthe process.This will include a definition and explanation of the following terms:
	//	///		a. Process gain
	//	///		b. Instrument gain
	///	//		c. Capacity
	///	//		d. Dead time
	///	//		e. Lag time
	///	//		f. Process stability
	///	//		g. Process disturbance
	//	///		h. Hysteresis
55				Analyze a controller that uses:
	///	//		a. Proportional control
	///	//		b. Reset control
	///	//		c. Derivative control
56	////	/		Draw a block diagram of an automatic feedback control system.
57				Use an electropneumatic trainer to setup and operate three systems:
	///	/	/	a. Uncontrolled
	///	/	/	b. Marginally controlled
	///	/	/	c. Optimally controlled
58				Set up, run, adjust, and troubleshoot a closed-loop automatic control system so that:
	////		/	a. Selection of proper valve operation provides fail safe operation.
	////		/	b. Selection of proper controller mode provides negative feedback loop.
	////		/	c. System runs as an optimally controlled process.
59	//	//	/	Identify different types of systems that are best controlled with various combinations of proportional/reset/derivative modes.
60				Given a process for each, select the instruments needed to provide control in each of the systems:
	//	//	/	a. Cascade
	//	//	/	b. Ratio
	//	//	/	c. Feed forward/feedback
61				Specify the valve operations and controller actions needed for each of the systems:
	//	/	//	a. Cascade
	//	/	//	b. Ratio
	//	/	//	c. Feed forward/feedback
62	/	//	//	Produce loop drawings of a ratio control system showing all instruments and their inner connections.

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
3				List the proper start-up procedures for the systems:
	//	///	//	a. Cascade
	//	///	//	b. Ratio
	//	///	//	c. Feed forward/feedback
64				Write a procedure for tuning (adjustment/set up) the controllers in:
	//	//	///	a. Cascade control system
	//	//	///	b. Ratio control system
65	/	///	///	Given a process, write the equation to provide feed forward control.
6	///	//	///	Select hardware--both analog and digital--to implement feed forward control.
67		////	//	Analyze the dynamic behavior of a control loop.
8				Use the data obtained in a frequency response analysis to:
		////	//	a. Make a Bode plot
		///	///	b. Derive information to use in the calculation of control mode settings.
69	/	//	///	Make a step analysis of process dynamic characteristics.
0				Use data from a step analysis to:
	/	///	//	a. Determine process gain
	/	///	//	b. Determine process phase shift
	/	///	//	c. Determine mode settings
71				Draw and discuss a typical microprocessor interfacing system used in automatic control
		//////		systems.
72		//// /	/	List four types of microprocessors used in systems and explain their applications.
3		//// /		Use assembler language algorithms.
74	//	////		Use relay ladder diagrams and software.
5		////		Use PC relay language.
76	/	///	///	State input and output speed, voltage and current characteristics of ten logic families and RS232C devices.
77	///	////		Identify electrical problems encountered when interfacing between logic families and RS232C devices.
78		////	///	Build and test interfaces between TTL and CMOS circuits.
9				Given a standard specification, determine whether or not a representative of any of the following logic circuits is operational:
	////	//	/	a. Gate, buffer/driver
	////	//	/	b. Buffer/driver
	////	//	/	c. Flip-flop
	////	//	/	d. Counter, shift register
	////	//	/	e. Selector
	////	//	/	f. Multiplexer/demultiplexer
	////	//	/	g. Comparator
0	///	////		Identify circuits that accomplish isolation.

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
81	//	///	/	Describe communication made possible by multiplexing.
82		//	////	Use a 74194 shift register as a digital multiplexer and as a demultiplexer.
83		///	//	Use a 4051 analog switch as an analog multiplexer and as a demultiplexer.
84		/	////	Build a digital and an analog multiplexed data communication system; each system to communicate information.
85	Rated #8			Identify microcomputer ICs and determine function and logic from manual.
86	Rated #10			Locate source of static hardware difficulties in small microcomputer systems.
87	Rated #9			Use logic analyzer for dynamic testing of microcomputer systems.
88	////	/		Properly ground and shield an instrument and/or identify potential ground loop, interference problems.
89				Use manufacturers' parts list and drawings concerning replacement parts for Robots/Automated Systems to:
	//// /		/	a. Identify part numbers
	//// /		/	b. Order replacement parts
	//// /		/	c. Install replacement parts
90				Adjust, troubleshoot, repair, and/or replace:
	//// //			a. Power supplies
	//// //			b. Servo amplifiers
	//// //			c. Motor control circuits
	//// //			d. Electronic sensors
	//// //			e. Transducers
91	////	/		Attach and replace connectors to wire and fiber optic cables.
92	////	//		Install low & high voltage and interconnecting signal (wire and fiber optic) cables.
93				Install, adjust, troubleshoot and repair or replace to manufacturer's specifications:
	//// /			a. Control devices
	//// /			b. Relays (electromechanical and solid state)
	//// /			c. Sensors
	//// /			d. Limit switches
	//// /			e. Transducers
	//// /			f. 1-phase and 3-phase electrical equipment
94		///	///	Program stepper motors.
95	////	/		Apply bridge circuits to measuring voltages and currents.
96	//// /	/		Replace components on circuit boards.
97	//// //			Solder and desolder electrical connections.
98	//// //			Install and remove circular (multipin), coaxial, and in-line plugs and receptacles.
99				Measure and set voltages and currents.
	//// /	/		a. Facility power
	//// //			b. Equipment power supply

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
100	//// //	/		Interpret industrial electrical symbols and line diagrams from printed material and/or graphic display systems.
101	///	////		Use operational amplifiers as followers, inverters, summers, integrators, and differentiators.
102	//// //	/		Describe ac and dc current.
103	//// /	/		Describe ac and dc electric motor operation.
104	////	//		Maintain pressure regulators.
105				Install, adjust, troubleshoot and repair or replace pneumatic:
	//// /	/		a. Airlines
	//// /	/		b. Pumps
	//// /	/		c. Gages
	//// /	/		d. Filters
	//// /	/		e. Control valves
	//// /	/		f. Actuators
	//// /	/		g. Cylinders
	//// /	/		h. Pressure switches
	//// /	/		i. Positioner relays
106	////	/	/	Adjust a pneumatic-sensor temperature controller to a specified mixed air temperature.
107	///	//	/	Properly use dampers, thermostats, switches, pneumatic positioners, linkage assemblies and accessories in pneumatic systems.
108	////		/	Conduct routine preventive maintenance on pneumatic equipment in accordance with manufacturer's instructions.
109	//	////	/	Sketch flow path symbols and air logic drawings.
110	//// /		/	Interpret flow path symbols and air logic drawings.
111	////	/	/	Identify and use proper size of pneumatic piping.
112	//	///		Control oil pressure and temperatures.
113	/	////		Null hydraulic servo systems.
114	////	//		Conduct routine preventive maintenance on hydraulic equipment in accordance with manufacturer's specifications.
115	///	/		Install programmable controllers.
116				Program and/or reprogram PCs (drum, relay, and microprocessor types) for specific sequence of events in performing an application.
	///	////		a. Prepare a flow chart for a specific sequence of events in performing given application.
	////	///		b. Enter instructions into control unit.
	////	///		c. Run program to see if control unit executes properly.
	////	///		d. Edit or debug program as necessary.
	////	///		e. Download and upload system.
	///	////		f. Recognize and resolve hardware/software impedance matching problems.

	Must Know	Nice to Know	Don't Need to Know	Instrumentation and Control Technicians Proposed Competencies
117				Install, adjust, troubleshoot and repair or replace:
	////	//		a. Servo motors
	////	///		b. AC pump motors (vacuum and pressure)
	////	///		c. Speed-reduction units
	////	///		d. Clutches
	////	//		e. Stepping motors
	////	///		f. Mechanical drives for feedback system
118				Install, adjust, troubleshoot and repair or replace sensors for:
	////	/		a. Flow control
	////	/		b. Liquid-level control
	///	///		c. Ultrasonic control
	///	///		d. Optoelectric
	///	///		e. Tactile
	///	//		f. Video
119				Effectively select and utilize such test equipment as time-domain reflectometers,
	////	///		oscilloscopes, spectrum analyzers, function generators, chart recorders, and multimeters
				for trouble shooting and repair of electronic circuits.
120	//// //			Identify and demonstrate proper operation, care and maintenance of hand power tools.
121	//// //			Select and install the proper fastener for a given job.
122	//// /	//		Identify and use appropriate lubricant.
123	//// /	/	/	Maintain work log sheets.
124	////	////		Draw logic diagrams.
125	//// //			Read, understand and comply with requirements of service bulletins.
126	//// /	/		Convert measurements between English and SI systems.
127	//// ///			Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed
				machine.
128	//// ///			Use manufacturer's manuals to determine a machine's normal operating characteristics.
129	//// //	/		Interpret graphs and charts.
130	//// /	//		Read and use acceptable twelfth-grade English.
131	////	////	/	Perform trigonometric calculations.
132	////	//		Explain the difference between accuracy, precision, and repeatability.
133	//// /	/		Explain the difference between direct and indirect measurements.
134				Communicate:
	//// ///			a. Orally
	//// ///			b. Listening
	//// ///			c. Reading
	////	///		d. Write technical reports
	////	///		e. Graphically

Appendix F

Correlation of Competencies
to Course Content

8/5/87 [ACCOMP.WK1	BASIC CORE COURSES							TECHNICAL CORE						SPECIALTY COURSES				
JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	ALGEB	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA. / GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. ELEC. POWER AND EQUIPMENT	PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSOR I	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
1 Analyze, construct, and/or troubleshoot:																		
a. Series-parallel circuits			a					X										
b. Bridge circuits								X						b				
2 Analyze, construct, and/or troubleshoot series, parallel, or complex:																		
a. Resistive-inductive-capacitive (RLC) circuits			a					X						a				
b. Resonant circuits			b					X										
c. Filter circuits								X										
d. Polyphase circuits								X	d									
e. Amplifiers and equalization networks								X										
3 Set up instrumentation and measure a given voltage, current, resistance, power, and/or frequency using the appropriate equipment:																		
a. Volt-ohm-milliammeter (VOM)			a					X	a									
b. Digital multimeter (DMM)			b					X	b									
c. Frequency counters			c					X							c	c		
d. Signal generators			d					X										
e. Capacitor-inductor analyzers								X										
f. Impedance bridges								X										
g. Oscilloscopes			g					X	g									
h. Sweep generators								X										
i. Spectrum analyzers								X										
j. Cable-fault analyzers								X										
4 Read and sketch electronic schematics.				X				X	X									
5 Record data and design curves and graphs.									X									
6 Build and test interfaces between transistor-transistor-logic (TTL) and complementary metal-oxide semiconductor (CMOS) circuits.															X			
7 Explain the role of timing in communication; distinguish between synchronous and asynchronous transmission.																	X	
8 Identify microcomputer integrated circuits (IC) and determine function and logic from manual.								X										
9 Use logic analyzer for dynamic testing of microcomputer systems.												X					X	
10 Calibrate or check calibration of:																		
a. Test instrument meters													a			a		
b. Frequency counters													b			b		
c. Spectrum analyzers													c			c		
11 Describe and demonstrate multiplexing and demultiplexing.															X		X	
12 Describe how to recognize static electricity problems and how to rectify them.								X										

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES							TECHNICAL CORE							SPECIALTY COURSES				
	ALGEBRA	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA. /GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. POWER AND EQUIPMENT	ELEC. PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSOR I	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
13 Construct, troubleshoot, repair, and/or replace the following:																	
a. Series-parallel circuits			a					X									
b. Voltage-divider circuits			b					X									.
c. Resistive-inductive-capacitive (RLC) series/parallel resonant filter circuits			c					X						b c			
d. Polyphase circuits									d						d		
e. Diode circuits								X									
f. Single- and multi-stage amplifiers								X									
g. Power supply circuits, regulated and unregulated								X	g								.
h. Active filter circuits								X									
i. Oscillator circuits								X									
j. Motor or phase-control circuits								X	j								
k. Logic gates								X							k		k
l. Flip-flops								X							l		l
m. Registers and counters								X							m		m
n. Clock and timing circuits								X							n		n
o. Logic arithmetic circuits								X							o		o
p. Encoders and decoders								X							p		p
q. Multiplexers and demultiplexers															q		q
r. Memory devices																	r
s. Analog-to-digital (A/D) and digital-to-analog (D/A) circuits								X							s		s
t. Displays								X									
u. Representative digital systems																	
14 Describe capacity of a communications channel in terms of bandwith and baud-rate.												X					
15 Describe communication made possible by simplex, half-duplex and duplex links.												X					
16 List the precautions and the general procedures/steps taken in device transportation and installation.								X				X					
17 Write programs in the BASIC programming language.				X								X					
18 Program or reprogram erasable/programmable ROM (EPROM).								X									x
19 Repair data-storage equipment, and interface controllers.																	X
20 Align, analyze, troubleshoot, and repair and return to service:																	
a. Display terminals												a					a
b. Interface controllers												b					b
c. Printers												c					c
21 Define computer acronyms.																	
a. RAM				a								a					a
b. ROM				b								b					b
c. DOS				c								c					c
d. CRT				d								d					d
e. MODEM				e								e					e
f. daa				f								f					f
g. IC				g								g					g
h. CPU				h								h					h
i. EPROM				i								i					i

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES								TECHNICAL CORE							SPECIALTY COURSES				
	ALGEBRA	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICATIONS/GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. POWER AND EQUIPMENT	ELEC. PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSORS	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRUMENTATION	MICROPROC. II
22 Load, run, and understand operating system software.				X								X					X
23 Load, run, and understand diagnostic software, both local and remote.																	X
24 Demonstrate good, considerate, conscientious customer relations skills.																	
25 Use diagnostic hardware, firmware, and/or software.												X			X		X
26 Solder and desolder CMOS devices.								X									
27 Identify and explain the operating principles of each instrument that measures:																	
a. Pressure													a		a		
b. Liquid level													b		b		
c. Temperature													c		c		
d. Flow													d		d		
28 For a given application, specify the range, accuracy and type of instrument which measures:																	
a. Pressure													a	a			
b. Flow													b	b			
c. Temperature													c	c			
d. Liquid level													d	d			
29 Calibrate instruments used in measurement of:																	
a. Pressure													a	a			
b. Liquid level													b	b			
c. Temperature													c	c			
d. Flow													d	d			
30 Demonstrate use of various differential pressure-sensing flowmeters.													X		X		
31 Sketch a typical differential-pressure flow-sensing device and transmission channel.			X										X		X		
32 Install an orifice plate and venturi tube in pipes; measure pressure drops as functions of flow; calculate flows, based on nominal discharge coefficients, for each device.													X	X			
33 Calibrate an orifice plate and venturi tube by making a differential-pressure versus flow curve; calculate discharge coefficient.			X										X				
34 Measure temperature using the following types of electrical temperature measuring devices:																	
a. Thermocouple			a										a				
b. RTDs			b										b				
c. Optical			c										c				

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES							TECHNICAL CORE					SPECIALTY COURSES						
	ALGEBRA	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA. /GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; SEMICONDUCTORS; PULSE DIGITAL; DIGITAL ELECTRONICS; ADVANCED LINEAR; INDUSTRIAL ELECTRONICS	INDUST. ELEC. POWER AND EQUIPMENT	PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSOR I	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
35 Operate each of the following devices:																			
a. Linear potentiometer								X					a	a	a				
b. Rotary potentiometer								X					b	b	b				
c. Linear inductor								X					c	c	c				
d. Rotary inductor								X					d	d	d				
e. Linear variable differential transformer (LVDT)													e	e	e				
f. Flyball governor													f	f	f				
g. Strain gage													g	g	g				
36 Make measurements of linear and angular displacement, velocity and force with:																			
a. Linear potentiometer													a						
b. Rotary potentiometer													b						
c. Linear inductor													c						
d. Rotary inductor													d						
e. Linear variable differential transformer (LVDT)													e						
f. Synchromechanism													f						
37 Bond a series of strain gages a solid steel cylinder; hook-up gage as part of a measurement bridge and determine the characteristics of the homemade load cell.														I		I		I	
38 Use a pneumatic transmitter in a system to measure the following variables:																			
a. Temperature													a		a				
b. Level													b		b				
c. Flow													c		c				
d. Pressure													d		d				
39 Calibrate and align a pneumatic transmitter.														I		I			
40 Implement the operation of a closed-loop control system by performing the following:																			
a. Install closed-loop control components on a combination level-flow process.													a		a				
b. Connect the instruments to perform closed-loop control function													b		b				
c. Make instrument adjustments to provide optimum process control. Include controller tuning, transmitter range selection, and adjustment.													c		c				
41 Identify a method for a quality control evaluation and relate the effect each control-loop component on the quality of the process. This will include a definition and explanation of the following:																			
a. Process gain													a		a				
b. Instrument gain													b		b				
c. Capacity													c		c				
d. Dead time													d		d				
e. Lag time													e		e				
f. Process stability													f		f				
g. Process disturbance													g		g				
h. Hysteresis													h		h				

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES							TECHNICAL CORE						SPECIALTY COURSES				
	ALGEBRA	GEOM.	APPLIED PHYSICS	TECH. COMMUNICA./GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. ELEC. POWER AND EQUIPMENT	PROPERTIES OF MATERIALS	MECHANICAL & FLUID POWER	MICRO-PROCESSOR	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
42 Analyze a controller that uses:																		
a. Proportional control														a	a			
b. Reset control														b	b			
c. Derivative control														c	c			
43 Draw a block diagram of an automatic feedback control system.				X									X	X	X	X	X	
44 Use an electropneumatic trainer to setup and operate three systems:																		
a. Uncontrolled														a	a			
b. Marginally controlled														b	b			
c. Optimally controlled														c	c			
45 Set-up, run, adjust, and troubleshoot a closed-loop automatic control system so that:																		
a. Selection of proper valve operation provides fail safe operation.															a	a		
b. Selection of proper controller mode provides negat feedback loop.															b	b		
c. System runs as an optimally controlled process.															c	c		
46 Identify different types of systems that are best controlled with various combinations of proportional/reset/derivative modes.														X	X			
47 Given a process for each, select the instruments needed to provide control in each of the systems:																		
a. Cascade													a	a	a			
b. Ratio													b	b	b			
c. Feed forward/feedback													c	c	c			
48 Specify the valve operations and controller actions needed for each of the systems:																		
a. Cascade													a	a	a			
b. Ratio													b	b	b			
c. Feed forward/feedback													c	c	c			
49 Produce loop drawings of a ratio control system showing all instruments and their inner connections.				X									X	X	X	X	X	
50 List the proper start-up procedures for the systems:																		
a. Cascade													a	a	a			
b. Ratio													b	b	b			
c. Feed forward/feedback													c	c	c			
51 Write a procedure for tuning (adjustment/set up) the controllers in:																		
a. Cascade control system																		
b. Ratio control system															a	a	a	
															b	b	b	
52 Draw and discuss a typical microprocessor interfacing system used in automatic control systems.				X													X	
53 List four types of microprocessors used in systems and explain their applications.																	X	

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES							TECHNICAL CORE							SPECIALTY COURSES					
	ALGEBRA	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICATIONS/GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR	ELECTRONICS CLUSTER: SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. POWER AND EQUIPMENT	ELEC. APPARATUS	PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSORS	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
54 Use assembler language algorithms.														X					X
55 Use relay ladder diagrams and software.														X					X
56 Use PC relay language.											X			X	X				X
57 Identify electrical problems encountered when interfacing between logic families and RS232C devices.														X					X
58 Given a standard specification, determine whether or not a representative of any of the following logic circuits is operational:																			
a. Gate, buffer/driver									X										a
b. Buffer/driver									X										b
c. Flip-flop									X										c
d. Counter, shift register									X										d
e. Selector									X										e
f. Multiplexer/demultiplexer									X										f
g. Comparator									X										g
59 Identify circuits that accomplish isolation.									X										X
60 Properly ground and shield an instrument and/or identify potential ground loop, interference problems.																	X		X
61 Use manufacturers' parts list and drawings concerning replacement parts to:																			
a. Identify part numbers															a	a	a	a	a
b. Order replacement parts															b	b	b	b	b
c. Install replacement parts															c	c	c	c	c
62 Adjust, troubleshoot, repair, and/or replace:																			
a. Power supplies															a	a	a	a	a
b. Servo amplifiers															b	b	b	b	b
c. Motor control circuits											c				c	c	c	c	c
d. Electronic sensors															d	d	d	d	d
e. Transducers															e	e	e	e	e
63 Install low & high voltage and interconnecting signal (wire and fiber optic) cables.														X					X
64 Install, adjust, troubleshoot and repair or replace to manufacturer's specifications:																			
a. Control devices											a					a		a	
b. Relays (electromechanical and solid state)											b					b		b	
c. Sensors											c					c		c	
d. Limit switches											d					d		d	
e. Transducers											e					e		e	
f. 1-phase and 3-phase electrical equipment											f								
65 Apply bridge circuits to measuring voltages and currents.															X			X	
66 Replace components on circuit boards.									X										

8/5/87 !ACCOMP.WK1	BASIC CORE COURSES									TECHNICAL CORE								SPECIALTY COURSES					
JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	ALGEBI	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA. /GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR	SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. POWER AND EQUIPMENT	ELEC. PROPERTIES OF MATERIALS	MEDICAL & FLUID POWER	MICRO-PROCESSOR	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
67 Solder and desolder electrical connections.									X	X								
68 Install and remove circular (multipin), coaxial, and in-line plugs and receptacles.													I					
69 Measure and set voltages and currents.																		
a. Facility power									I									
b. Equipment power supply									I									
70 Interpret industrial electrical symbols and line diagrams from printed material and/or graphic display systems.				I					I									
71 Use operational amplifiers as followers, inverters, summers, integrators, and differentiators.									I									
72 Describe ac and dc current flow.									X	X								
73 Describe ac and dc electric motor operation.									X	X								
74 Maintain pressure regulators.											a							
75 Install, adjust troubleshoot and repair or replace pneumatic:																		
a. Airlines											a							
b. Pumps											b							
c. Gages											c							
d. Filters											d							
e. Control valves											e							
f. Actuators											f							
g. Cylinders											g							
h. Pressure switches											h							
i. Positioner relays											i							
76 Adjust a pneumatic-sensor temperature controller to a specified mixed air temperature.											X							
77 Properly use dampers, thermostats, switches, pneumatic positioners, linkage assemblies and accessories in pneumatic systems.											X							
78 Conduct routine preventive maintenance on pneumatic equipment in accordance with manufacturer's instructions.											X							
79 Sketch flow path symbols and air logic drawings.				X							X							
80 Interpret flow path symbols and air logic drawings.				X							X							
81 Identify and use proper size of pneumatic piping.											X							
82 Control oil pressure and temperatures.											X							
83 Hull hydraulic servo systems.											X							

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JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	BASIC CORE COURSES							TECHNICAL CORE						SPECIALTY COURSES				
	ALGEBI	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA. / GRAPHICS	COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. ELEC. POWER AND EQUIPMENT	PROPERTIES OF MATERIALS	MECHAN. & FLUIDI POWER	MICRO-PROCESSOR I	INSTR. & CONTRLS I	INDUSTRIAL ELECTRONICS I	CONTROL SYSTEMS I	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
84 Conduct routine preventive maintenance on hydraulic equipment in accordance with manufacturer's specifications.											X						
85 Install programmable controllers.																	
86 Program and/or reprogram PCs (drum, relay, and microprocessor types) for specific sequence of events in performing an application.															X		
a. Prepare a flow chart for a specific sequence of events in performing given application.				a											a		a
b. Enter instructions into control unit.															b		b
c. Run program to see if control unit executes properly.															c		c
d. Edit or debug program as necessary.															d		d
e. Download and upload system.															e		e
f. Recognize and resolve hardware/software impedance matching problems.															f		f
87 Install, adjust, troubleshoot and repair or replace:																	
a. Servo motors								X	a		a				a		
b. AC pump motors (vacuum and pressure)								X	b		b				b		
c. Speed-reduction units								X	c		c				c		
d. Clutches								X	d		d				d		
e. Stepping motors								X	e		e				e		
f. Mechanical drives for feedback system								X	f		f				f		
88 Install, adjust, troubleshoot and repair or replace sensors for:																	
a. Flow control														a	a		a
b. Liquid-level control														b	b		b
c. Ultrasonic control														c	c		c
d. Optoelectric														d	d		d
e. Tactile														e	e		e
f. Video														f	f		f
89 Effectively select and utilize such test equipment as time-domain reflectometers, oscilloscopes, spectrum analyzers, function generators, chart recorders, and multimeters for trouble shooting and repair of electronic circuits.			X					X	X			X	X	X	X	X	X
90 Identify and demonstrate proper operation, care and maintenance of hand power tools.																	
91 Maintain work log sheets.				X			X										
92 Draw logic diagrams.				X													
93 Read, understand and comply with requirements of service bulletins.				X													X
94 Convert measurements between English and SI systems.			X										X	X	X	X	X
95 Interpret graphs and charts.				X													
96 Read and use acceptable twelfth-grade English.				X													

8/5/87 I&CCOMP.WK1	BASIC CORE COURSES								TECHNICAL CORE									SPECIALTY COURSES							
JOB COMPETENCIES FOR INSTRUMENTATION AND CONTROL TECHNICIANS	ALGEBI	GEOM.	PT & APPLIED PHYSICS	TECH. COMMUNICA./GRAPHICS		COMPUTER BASICS	ECON IN TECH.	INDUSTRIAL RELATIONS	ELECTRONICS CLUSTER: DC & AC ELECTRICITY; PULSE DIGITAL; ADVANCED LINEAR; SEMICONDUCTORS; DIGITAL ELECTRONICS; INDUSTRIAL ELECTRONICS	INDUST. ELEC. POWER AND EQUIPMENT	PROPERTIES OF MATERIALS	MECHAN. & FLUID POWER	MICRO-PROCESSOR I	INSTR. & CONTROLS	INDUSTRIAL ELECTRONICS	CONTROL SYSTEMS	ANALYTICAL INSTRU-MENTATION	MICROPROC. II
97 Perform trigonometric calculations.	X																							
98 Explain the difference between accuracy, precision, and repeatability.														X	X	X	X	X						
99 Explain the difference between direct and indirect measurements.														X				X						
100 Communicate:																								
a. Orally					a																			
b. Listening					b																			
c. Reading					c																			
d. Write technical reports					d																			
e. Graphically					e																			

APPENDIX G

Guide for Articulation Agreement

ARTICULATION AGREEMENT BETWEEN LEANDER I.S.D. AND AUSTIN COMMUNITY COLLEGE

An articulation agreement was developed between Leander I.S.D. and Austin Community College with Principles of Technology I and II as the base courses for the secondary/postsecondary agreement. These two courses will be pre-requisites for entry into the 2+2 student program. No college credit will be given for these two courses and students will be encouraged to have completed Algebra I and/or Geometry or to be enrolled concurrently in one or the other of these mathematics courses. In addition, the Career Aptitude Placement Survey can be given with the 2+2 program students to identify those with a definite aptitude for electronics or related areas.

During the junior (11th) year a student will take PT I for both semesters and then DC Electronics for one semester and AC Electronics for one semester. These DC/AC Electronics courses will receive high school elective credit and concurrent Austin Community College credit (4 semester hours for each course).

During the senior (12th) year a student will take PT II for both semesters and a Semi-Conductor course for both semesters. The Semi-Conductor course will be an elective high school credit course and 4 hours will be applied in escrow credit for Austin Community College. Graphics and/or Drafting and Computer Basics course will be strongly recommended as additional courses for the senior year. These courses of PT I and PT II, DC/AC Electronics, Semi-Conductor, Drafting, Graphics, and Computer Basics will not be limited to only the 2+2 Program students but will be open to any high school student who might be interested in these classes.

Once the 2+2 student has graduated from high school, there are at least three vocational options for him/her to follow. He/she can enter the job market with a potentially higher job skill level. He/she can enter A.C.C. and pursue an Associate Degree in Electronics with the concurrent escrow hours being applied to his/her degree plan once he/she has completed six hours of college level credit work at A.C.C. This concurrent credit would allow a student to complete an Associate Electronics Degree in 1 1/2 years, rather than 2 years. The third option of this 2+2 student program is to complete an Associate Degree in Instrumentation and Control that would be a full 2 year program with these students still receiving college credit for those high school courses in escrow

once he/she has completed 6 hours at A.C.C.

A chart is included that indicates the plan proposed between the two entities, Leander I.S.D. and Austin Community College.

ARTICULATION AGREEMENT
FOR
INSTRUMENTATION AND CONTROL TECHNOLOGY
ASSOCIATE DEGREE

LEANDER HIGH SCHOOL				AUSTIN COMMUNITY COLLEGE				
JUNIOR		SENIOR		FRESHMAN		SUMMER	SOPHOMORE	
Principles of Technology I		Principles of Technology II			Applied Physics (Class) (4/0/4)		English Composition (1613)	Technical Communi-cations (1633)
Geometry or Algebra		Semiconductors		Applied Math I (Algebra) (1743)	Applied Math II (Electronic) (2123)		Property of Material (2/0/2)	Economics in Technology (2/0/2)
D.C. Electricity (1148)	A.C. Electricity (1148)	Graphics	Computer Basics	Pulse Digital Electronics (2084)	Advanced Linear (2104)	Digital Logic (2094)	Micro-processors I (2114)	Micro-processors II (2214)
				Mechanical & Fluid Power Systems (2/4/4)	Industrial Electrical Power & Equipment (3/4/5)		Texas Government (2023)	Industrial Relations (2/0/2)
				Funda-mentals of I&C (3/4/4)	Industrial Electronics (2164)	Control Systems (3/4/5)	Analytical Instrumen-tation (2/4/4)	

APPENDIX H

Course Outline

D.C. ELECTRICITY

COURSE OUTLINE

This course covers current, voltage, and resistance in DC circuits--including series, parallel, and complex circuits. It also includes steady-state analysis of magnetism, electromagnetics, mutual induction, RL circuits, capacitance, and RC circuits. In addition, the course reviews how to care for and use power supplies, function generators, meters, and oscilloscopes.

Course Outline

1. Basic DC Circuits
   - A. Voltage, Current, and Resistance
   - B. Scientific Notation and Metric Prefixes
   - C. Ohm's Law and Power
   - D. Series Circuits
   - E. Parallel Circuits
   - F. Parallel Circuit Analysis
   - G. Series-Parallel Circuits
   - H. Voltage Dividers and Power
   - I. Kirchoff's Laws
   - J. Advanced Methods of DC Circuit Analysis
   - K. RC Time Constant
   - L. L/R Time Constant

A.C. ELECTRICITY

COURSE OUTLINE

This course is the study of reactance, impedance, phase relationship, AC power, transformers, vector notation, and resonance. It also includes information about how to analyze series, parallel, and complex reactive circuits. In addition, the course reviews how to care for and use power supplies, function generators, meters and oscilloscopes.

Course Outline

I. Basic AC Circuits
   - A. Alternating Current
   - B. AC Sine Wave
   - C. Measurements made with the Oscilloscope
   - D. Phase Shift
   - E. Resistive Circuits
   - F. Capacitance
   - G. RC Circuit Analysis
   - H. Inductance and Transformers
   - I. RL Circuit Analysis
   - J. RC and RL Time Constants
   - K. RLC Circuit Analysis
   - L. Phasor Algebra
   - M. Complex RLC Circuit Analysis
   - N. Resonance

SEMICONDUCTOR

COURSE OUTLINE

This course covers the theory and operation of semiconductor devices, including circuit analysis procedures and troubleshooting techniques. It reviews circuit applications, including power supplies and basic amplifier circuits. In addition, the course covers how to care for and use power supplies, function generators, meters, and oscilloscopes.

Course Outline

I. Introduction
   A. Semiconductor Devices
   B. Historical Background
   C. Discrete Semiconductor Devices
   D. Linear Integrated Circuits
   E. Kirchhoff's Laws
   F. Voltage Dividers
   G. Current Dividers
   H. RC Circuits
   I. RC Analysis
   J. dc/ac Superposition
   K. Thevenin's Theorem
   L. Using the Computer for Circuit Analysis

II. Semiconductor Materials and pn Junctions
   A. Atoms
   B. Atomic Bonding
   C. Conduction in Semiconductor Crystals
   D. n-Type and p-Type Semiconductors
   E. pn Junctions
   F. Biasing and pn Junctions

III. Diodes and Applications
- A. Rectifier Diodes
- B. Half-Wave Rectifiers
- C. Full-Wave Rectifiers
- D. Rectifier Filters
- E. Trouble-Shooting Rectifier Circuits
- F. Diode Clipper and Clamper Circuits
- G. Voltage Multipliers
- H. Diode Data Sheets
- I. Computer Analysis

IV. Special Diodes
- A. Zener Diodes
- B. Zener Voltage Regulation
- C. Varactor Diodes
- D. Schottky Diodes
- E. Tunnel Diodes
- F. Other Types of Diodes

V. Bipolar Transistors
- A. Transistor Construction
- B. Basic Transistor Operation
- C. Amplification
- D. Common-Base Configuration
- E. Common-Emitter Configuration
- F. Common-Collector Configuration
- G. Transistor Parameters and Ratings
- H. Transistor Testing
- I. Packages and Terminal Identification
- J. Computer Analysis

VI. Transistor Biasing
- A. Purpose of Biasing
- B. The dc Operating Point
- C. Base Bias

D. Emitter Bias
E. Voltage Divider Bias
F. Collector Feedback Bias
G. Trouble-Shooting Bias Circuits
H. Computer Analysis

VII. Small-Signal Amplifiers
A. Small-Signal Operation
B. Transistor Equivalent Circuits
C. Common-Emitter Amplifier
D. Common-Collector Amplifier
E. Common-Base Amplifier
F. Multistage Amplifiers
G. Trouble-Shooting
H. Computer Analysis

VIII. Power Amplifiers
A. Class A Amplifiers
B. Class B Push-Pull Amplifiers
C. Class C Amplifiers
D. Trouble-Shooting
E. Computer Analysis

IX. Field-Effect Transistors
A. The Junction Field-Effect Transistor (JFET)
B. JFET Characteristics and Parameters
C. The Metal Oxide Semiconductor FET (MOSFET)
D. MOSFET Characteristics and Parameters
E. JFET Biasing
F. MOSFET Biasing
G. Computer Analysis

X. FET Amplifiers
A. Small Signal Operation
B. FET Amplification
C. Common-Source Amplifier

D. Common-Drain Amplifier
E. Common-Gate Amplifier
F. Multistage FET Amplifiers
G. Trouble-Shooting
H. Computer Analysis

XI. Amplifier Frequency Response
A. General Concepts
B. Millers' Theorem and Decibels
C. Low-Frequency Analysis of a Bipolar Amplifier
D. Low-Frequency Analysis of an FET Amplifier
E. High-Frequency Analysis of a Bipolar Amplifier
F. High-Frequency Analysis of a FET Amplifier
G. Total Amplifier Response
H. Tests and Measurements
I. Computer Analysis

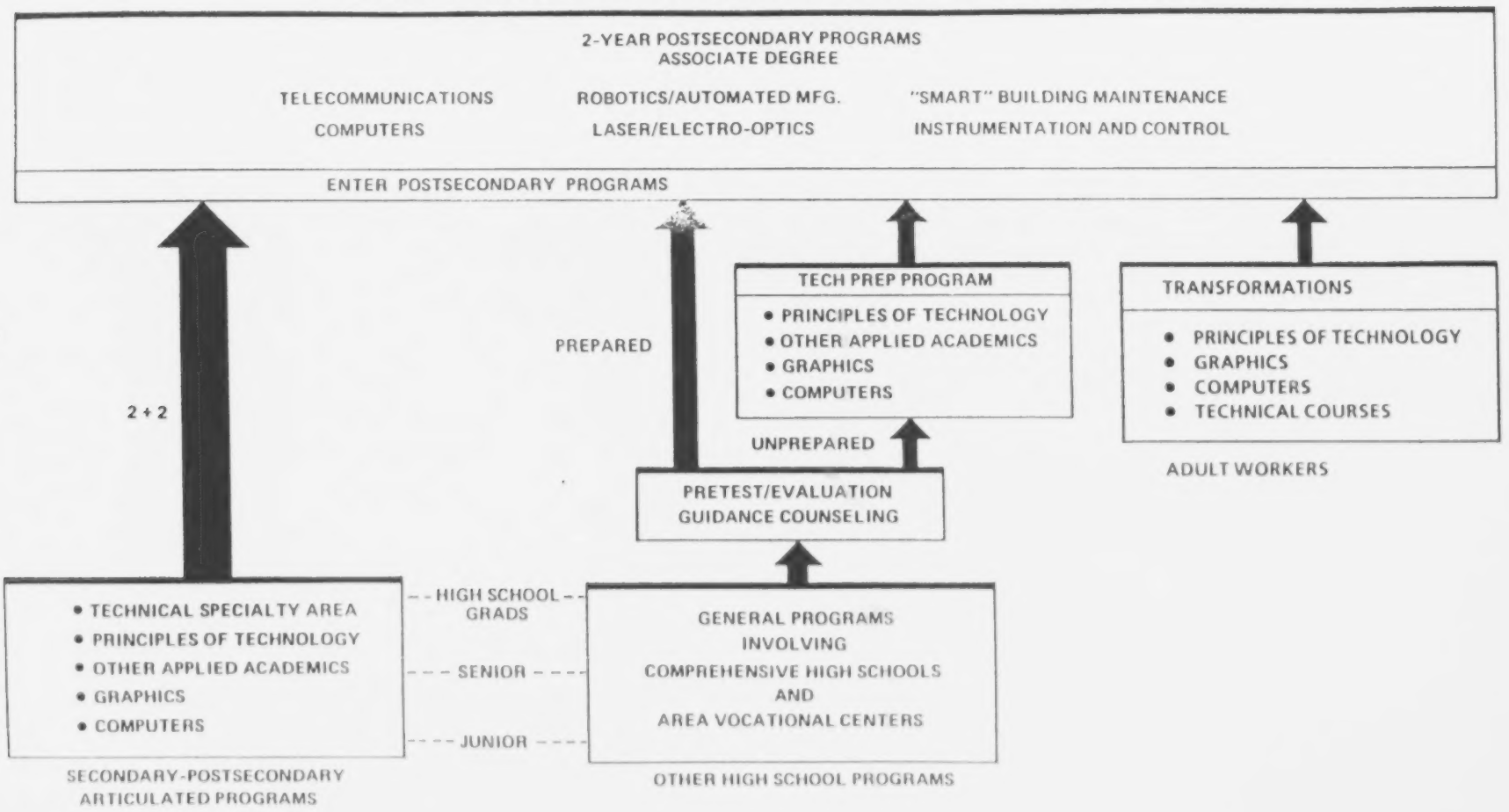
XII. Thyristors and Unijunction Transistors
A. The Shockley Diode
B. Silicon-Controlled Rectifier (SCR)
C. SCR Applications
D. Silicon-Controlled Switch (SCS)
E. The Diac and Triac
F. The Unijunction Transistor (UJT)
G. The Programmable UJT (PUT)

XIII. Optoelectronic Devices
A. The Characteristics of Light
B. Photoconductive Cells
C. Photodiodes
D. Phototransistors
E. Solar Cells
F. The Light-Activated SCR (LASCR)
G. The Light-Emitting Diode (LED)
H. The Laser Diode
I. Optical Couplers

Appendix I

Alternative Entry Points
for I&C Curriculum

PROCESS FOR ALLOWING STUDENTS, WHO DID NOT PARTICIPATE IN 2 + 2 ARTICULATED CURRICULUM, TO ENTER ADVANCED TECHNOLOGY PROGRAMS



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Appendix J

Guidelines for Developing Lecture
and Laboratory Facilities

INFORMATION ABOUT LAB MANAGEMENT/ FACILITIES REQUIREMENTS/EQUIPMENT LIST

Tips about lab management

Just as good management makes good business, good lab management makes good labs. About 40 percent of this curriculum is spent in hands-on labs; therefore, about 40 percent of your instructional preparation is spent in facilitating this aspect of the curriculum.

Lab time fosters learning and gives students a chance for experimentation. Lab time is also a time for students to learn work habits that will benefit them on the job in their future careers. The lab component is important because it helps student develop skills necessary of good technicians.

A clean, businesslike 'bright' and organized lab doesn't need to be as quiet as a study hall—to the contrary. Noise means learning is taking place. However, there are acceptable noise limits. Too much noise is obviously detrimental to learning. But the right level of noise indicates activity—that something is happening, that an excitement is taking place about learning. Like Tom Sawyer painting the fence, students involved in a vibrant, exhilarating lab will attract new students who want to see what all the fun is about.

Be aware of noise outside the lab. Outside noise is not desirable, and can be controlled with acoustics and other measures. Obviously, the lab should be properly heated, air-conditioned and ventilated.

Physical discomfort breeds behavior problems. Be sure the lab is properly lighted, since ill lighting promotes an unsafe and inefficient place to work.

When you begin teaching a course in the I&C curriculum, you may wish to set up all the lab activities yourself. Later on, you might want to allow some of your more capable students to help you set up the labs for the other students. Once you've developed your students' ability to help you set up equipment, you'll have more time to assist students in other activities.

In fact, you may want to use this same procedure for setting up the equipment for demonstrations. In other words, you may want to allow some of your most capable students to perform demonstrations for the class. This has the benefit of giving your students the opportunity to take responsibility for the kinds of duties they may face during their careers as technicians.

This practice in performing before their peers may also help your students develop public speaking skills and confidence in their ability. As your class begins to become accustomed to the course, you may wish to involve them further in setting up the equipment for all of the lab activities. Obviously, this will give your students a chance to try their hands at coordinating the kinds of skills that are necessary in the marketplace.

It's also important to know what equipment is in stock, so you may also want to set up an inventory system to keep a record of equipment items. Inventory records will help you prepare budgets from year to year and plan for the purchase of additional equipment, as well as help you be aware of equipment losses.

You can keep your equipment records on index cards. You may wish to ask a student to help you in this endeavor, as well. This will give the student training in inventory control, and will provide you with some help in maintaining your lab equipment records.

Other lab management tips you may wish to consider are:

1. Don't assume your students really know how to use a meter or any of the other instruments in the lab. You may want to give "practical" exams that test students on their ability to use the equipment by having them operate the equipment while you observe.

2. In many cases, students will work together on labs. Be sure that each student has the opportunity to work with the equipment. You may also want to rotate lab partners—or make sure students take turns doing the same experiment or different experiments.

3. There are times when students must rotate between labs. Sometimes, they'll use the same equipment, but will do different things.

4. Some labs may have only one lab setup for the entire class. This type of lab is more like a detailed, highly structured demonstration. However, students must still participate if the lab is to be used to its best advantage. Students can take data or take turns doing some portion of the lab so that they can see what's happening firsthand.

5. You should do each lab yourself before having the students do it. Doing this helps you identify portions of the lab the students may find difficult.

6. Remember: the purpose of a lab is twofold. You want your students to see the experiment, get practice in setting up the equipment, and use the

equipment. You want to help your students develop the ability to think and work with their hands at the same time. This is because technicians in the workplace need both kinds of skills and will need preemployment practice at coordinating these capabilities.

Lab design/facilities consideration

When equipment is used to teach specific principles, it's essential that some real apparatus—typical of that used in today's workplaces—also be used. It's not enough to demonstrate the principle alone; students must see and understand the principle as applied with the standard apparatus currently used in the technology.

Labs are discussed here with respect to size, utility services, storage, furniture arrangements and safety considerations. Both new construction and retrofitting of existing facilities are covered in this discussion.

What are "clean" laboratories?

Most labs of the I&C curriculum are classified as "clean" labs. This means they're typified by:

- Apparatus that's portable and easily assembled, disassembled and stored.
- Light-duty tools; few power tools.
- Student work surfaces and tables that do not require hardened surfaces or heavy construction.
- Environment of room similar to that found in the traditional classroom—drop ceiling, fluorescent lighting, and linoleum floor coverings.
- Little or no use of oily or corrosive liquids.

What size should the lab be?

The major factors in the selection or construction of a lab facility include: (1) student load, (2) apparatus requirements, (3) experimental format, (4) single versus multiple purpose, and (5) dedicated subject use versus multiple subject use.

The optimal student load for a lock-step experimental format is between 12 and 18 students. A self-paced experimental format permits the school a greater degree of flexibility in determining the size of the lab facility. Generally, clean laboratories should have a minimum space allotment of 40 square feet per student. This allotment includes work area, storage space and access space, and is stipulated for lab rooms intended as lab rooms only—not as a combined classroom/laboratory room

(multiple purpose). Multiple-purpose classroom sizes can be determined by the following formula:

$$\text{Section capacity in number of students} \times \left[\begin{array}{c}\text{Laboratory space} \\ @\ 40\ \text{ft}^2/\text{student}\end{array} + \begin{array}{c}\text{Classroom space} \\ @\ 15\ \text{ft}^2/\text{student}\end{array}\right] = \text{Minimum space}$$

For rooms used as labs for more than one subject, additional storage space must be provided for experimental apparatus.

What are the utility service requirements?

When the maximum number of lab work stations has been identified and the size of the rooms determined, the requirements for utility services should be considered. Utility services include: electricity for outlets and lighting and the piped services of gas (optional), compressed air, water and drain. Related considerations are the number of connections to each required service, the arrangement of service connections, and the safety devices and precautions built into the utility service systems.

Electricity provides power for lighting and for activating many devices used in lab experiments. Most electrical service for clean labs is single-phase, 120-volt AC. The amount of light needed at bench-top surface varies with the subject and often with the type of work to be performed. A general rule of thumb is that it should never be 100 candle power less than the amount stipulated by state/municipal regulations. Fluorescent lighting that's set diagonally to the orientation of work surfaces maximizes the amount of light reaching the work surface. The lighting circuits should be isolated from the circuits providing power to outlets in the lab.

Electricity must be delivered at workbench outlets according to a unique scheme. Each workbench should have its own circuit or circuits. In addition, each circuit must be protected by its own circuit breaker. Ideally, each lab station should have its own circuit. This arrangement prevents the disruption of power at all lab stations when one circuit becomes overloaded. The circuit breaker may be located remotely from the bench; however, cutoff switches for each circuit should be located at one end of the bench.

Some clean labs require one or more of the piped utility services of gas (optional), compressed air, vacuum, water and drain. Some of these services can be provided without the permanent installation of pipes. Compressed air and vacuum can be provided by the use of portable manual or electric pumps. Gas can be provided by portable torches or bottled compressed gas, connected by hose to a burner. The

decision to use portable alternatives in place of permanent installation of pipes is usually based upon frequency and quantity of use, economic considerations and convenience.

Water service can be a particularly troublesome problem in retrofitting a room for lab use. It's little trouble to bring water in; the difficulty is in getting the water out. Traditionally, the drains need to be installed either below floor level or through a wall. Installing a drain into the floor can be very costly. Taking the drain through a wall results in the use of peninsula lab benches rather than the more efficient island lab benches. One innovation in retrofitting is the use of a drain basin below a lab sink fitted with a sump pump; this may simplify the removal of water from a retrofitted lab.

What about ventilation?

Even clean laboratories may involve the use of substances that can be potentially noxious or toxic. Therefore, ventilation requirements must be considered. Requirements vary from state to state—comply with local guidelines.

What about furniture arrangements?

Clean-lab furniture is generally found in two basic designs: low-form and standard. The height of low-form furniture is 28 to 30 inches from the floor to the top working surface. It's intended to be used by students who are seated. Low-form furniture may or may not have drawers or cabinets; normally, this design has a composition surface. Traditional or standard furniture has a floor-to-working-surface distance of 36 to 38 inches. In addition, this type of furniture usually has storage space (drawers and cabinets). This lab furniture may be placed against the walls—jutting out into the room in peninsula fashion—or it may be isolated from the wall in an island style. The island style provides the greatest efficiency and maximum flexibility. Many companies manufacture lab furniture with various arrangements of storage areas and utility service outlets.

Lab furniture can provide a great deal of room for storage of materials, but it may not provide a total solution. If additional storage space is needed, tall cabinet storage along the lab walls may help. In some instances, a separate area may be dedicated to storage. In all instances, the issues of security and safety must be given serious consideration.

What about safety?

The issue of safety—personnel safety, equipment safety, and security—is of increasing concern.

The lab is an area of increased hazard. Therefore, you should place much emphasis on safety. This emphasis can be accomplished through the installation of safety devices and the enforcement of safety procedures. The use of circuit breakers and separate disconnect switches for each circuit of each bench previously have been discussed. In addition, the main room lights should be isolated from any other electrical circuits. There should be an emergency electrical disconnect switch for all electrical circuits in the lab except for the main room lighting circuit. This emergency switch should be wired to deactivate all gas and water utility services and to activate an alarm. Such an arrangement is called a "scram circuit." The scram switch should be placed near the main room exit, and can be placed behind a breakable glass window to prevent accidental engagement.

Many other safety precautions should be routine. Cabinets, drawers and separate storage areas should be locked when not in use. Students should be required to memorize and practice certain basic safety procedures. Personal protective equipment such as aprons, safety glasses, gloves, etc., should be provided and required as conditions warrant. There should never be fewer than two people in an area when experiments are being performed. (The buddy rule is particularly important when high voltages are present.)

Lab work should never be performed in the absence of qualified supervisory personnel. Instructors and lab assistants who are responsible for conducting lab experiments should be familiar with the various federal, state and local laws and regulations governing the use and control of toxic or explosive substances and certain hazardous equipment. Many states also have regulations governing the availability and use of safety devices in school labs. Fire blankets and extinguishers, eyewash bottles or fountains, and emergency showers may be required by law.

What kind of tools will students use?

The tools required for experiments performed in the clean labs generally are light-duty and small in size. A few small power tools may be employed. They should be double-insulated and have a proper grounding wire. Storage and control of tools can be achieved either through a central tool check-in/check-out system or by a station of lockable drawers that are inventoried when opened and closed by the lab assistant. Most tools required in clean labs will fit in a standard 5 1/2" x 6" x 18" drawer; thus, one drawer at each lab station can be outfitted and designated for this use.

Tips about equipment purchase

The lab teacher's responsibility includes procuring equipment items, identifying them, storing them and maintaining them. This is a large task. The following steps aid you in the task of constructing your order list of equipment.

Step 1: Order your equipment catalogs. In addition to the regular science supply catalogs from Sargent-Welch, Cenco, Fisher Scientific, etc., and normal vocational supply catalogs from Brodhead Garrett or SASCO, you need the following: General supply—such as W.W. Grainger, Inc. (312) 928-1912. Specialized instruments—such as Omega Engineering, Inc. (203) 359-1660

Step 2: While waiting for your catalogs, review the equipment list and the labs to gain a "feel" for the labs.

Step 3: Divide the equipment list into three categories.
Category 1: Equipment on hand and available for use in course.

Category 2: Equipment needed, nonconsumable.

Category 3: Materials of an expendable nature (that will be replaced periodically).

Step 4: If you're required to bid all items above a certain dollar figure, you could subdivide Category 2 of Step 3.

Step 5: Carefully examine the items you initially placed in Category 1. Is each item compatible with other equipment to which it must be connected in the lab?

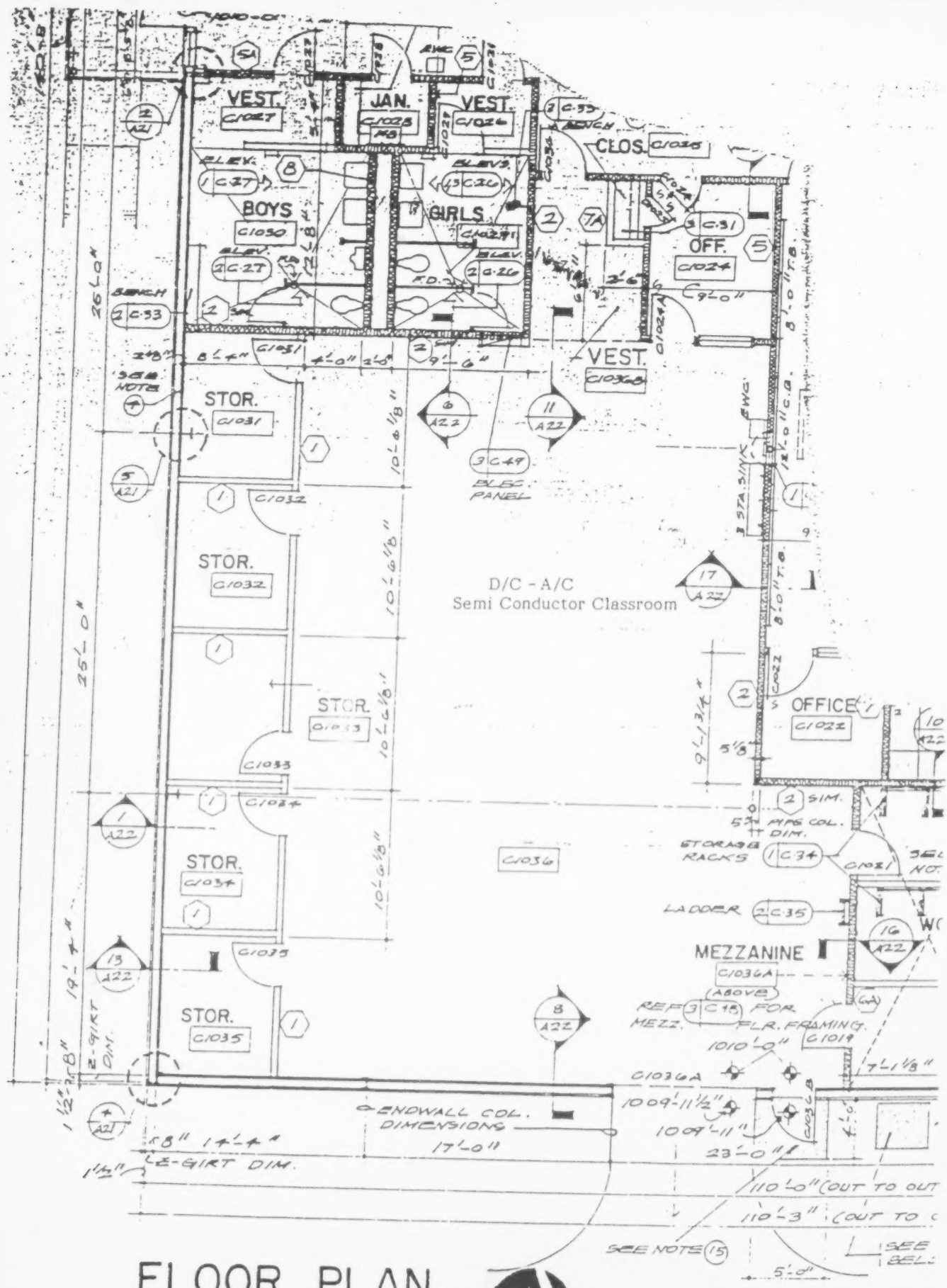
Step 6: Naturally, you want the equipment to be rugged and flexible, yet economical. This is the tough part. One way to judge the level of flexibility and ruggedness is to look at several labs where that item is used. Buying equipment based solely on how it's used in the first experiment can present trouble down the line.

All these steps will be influenced by your experience. In many instances, you'll be faced with following one of two major paths. These are: (1) procuring materials in a disassembled kit form; or (2) getting the materials in assembled specific apparatus. The first option provides economy, flexibility and potentially greater student involvement. The second option provides convenience, time savings, and minimal

student frustration. Your ability, approach and the dollars available help you select the path you should take.

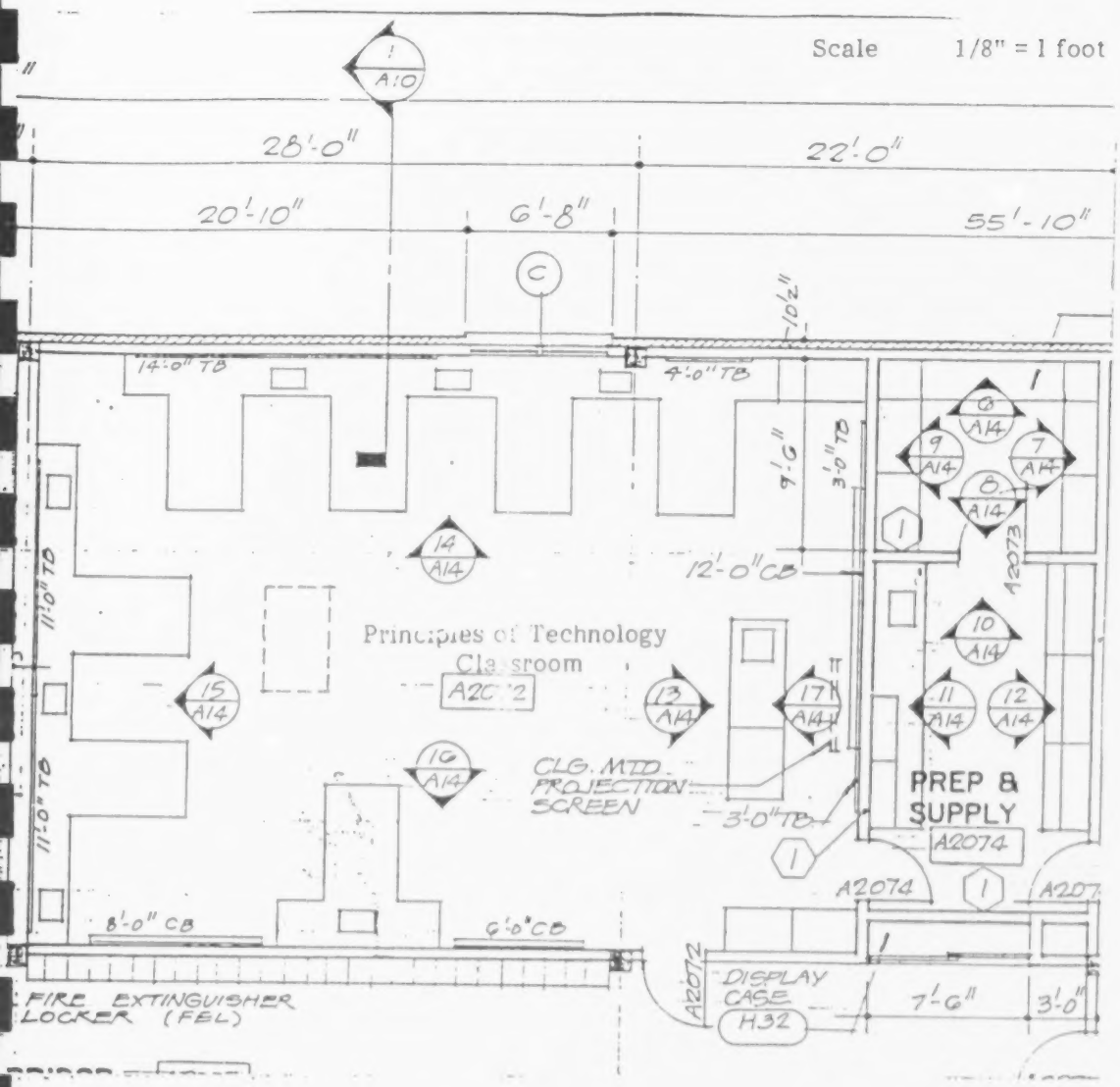
Step 7: Consider your equipment suppliers. What's their track record? What service after the sale do they provide? How do they handle damaged or defective items? Do they have someone (that you can contact) who is technically knowledgeable about the items they offer? Do they offer "package" deals? Do they give discounts for quantity?

Step 8: Submit your lists—and be ready to justify each item. You might consider sitting down with your school's purchasing director and work for his/her cooperation in not allowing the order to be based only on price. Be flexible on where the equipment item comes from, but don't compromise on the capabilities of the item.



FLOOR PLAN

SCALE: 1/8" = 1'-0"


Scale 1/8" = 1 foot
28'-0"
22'-0"
20'-10"
6'-8"
55'-10"
14'-0" TB
4'-0" TB
12'-0" CB
Principles of Technology
Classroom
A2072
CLG. MTD. PROJECTION SCREEN
3'-0" TB
PREP & SUPPLY
A2074
A2073
A2072
DISPLAY CASE H32
7'-6"
3'-0"
8'-0" CB
6'-0" CB
FIRE EXTINGUISHER LOCKER (FEL)

Appendix K

Reference Materials for the
Instrumentation and Control Curriculum

Course Title	Reference Material
Principles of Technology	Principles of Technology Center for Occupational Research and Development Waco, Texas
Geometry	Geometry Jurgensen, Brown, and King Houghton Mifflin Company Boston, Massachusetts
DC Electricity	Basic Electricity and DC Circuits Oliva & Dale Howard W. Sams & Company Indianapolis, Indiana
AC Electricity	Basic AC Circuits Fulton & Rawlins Howard W. Sams and Company Indianapolis, Indiana
Semiconductors	Electronic Devices Thomas L. Floyd Charles E. Merrill Publishing Columbus, Ohio
Graphics	Technical Graphics Center for Occupational Research and Development Waco, Texas

	Engineering Drawings and Graphics Technology T.E. French McGraw-Hill Book Co. New York, New York
Computer Basics	Computer Mathematics: Basic Programming with Applications Norris and Poirot
Applied Math I	College Algebra with Applications Munem and Foulis Worth Publishers, Inc.
Pulse Digital Electronics	Fundamentals of Pulse and Digital Circuits Ronald J. Tocci Charles E. Merrill Publishing Columbus, Ohio
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Fundamentals of I&C	Fundamentals of Instrumentation and Control Center for Occupational Research and Development Waco, Texas

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Industrial Electrical Power & Equipment	Electrical Power Technology T. Wildi John Wiley and Sons New York, New York
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Microprocessors I	Microprocessors-Microcomputer Technology Frederick F. Driscoll
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